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THE PRODUCTION OF ILLUMINATING GAS AND COKE IN BY-PRODUCT COKE OVENS.[1]

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IN June last the writer paid a visit to the gas works of Halifax, Nova Scotia. The illuminating gas is produced in by-product coke ovens, and the excess of heating gas not required for the ovens is collected in separate holders and piped to industrial establishments; the coke produced is sold for domestic use and boiler fuel.

The first by-product oven was that of Carvès, erected in 1867. Since then a great variety of coke ovens have been constructed for saving the by-products, which have thus become a valuable article of commerce, furnishing numerous important compounds used in the arts. Halifax is, so far as the writer knows, the first city in America to be lighted by gas made in the by-product coke ovens. In Europe, however, the gas from an Otto-Hoffmann plant has been sold to a gas works for several years. It has long been known from studying the analyses of coke-oven gases that those obtained at certain stages of the process were suited for illuminating purposes, but the first practical application of the knowledge here seems to have been made at Halifax, where it has proved an undoubted success.

Enormous works are now in process of erection at Everett for the purpose of supplying Boston in the same way with illuminating gas, heating gas, and coke. The plant will consist of 400 Otto-Hoffmann

[1] Reprinted from *The Engineering and Mining Journal* of October 8 and 15, 1898.

ovens, with a daily capacity of about 2,000 gross tons of coal. It will be equipped with modern mechanical appliances for the cheap handling of coal and coke, a complete system of condensation and purification and ammonia stills. The gas will be stored in a holder having a capacity of 5,000,000 cubic feet. The coke to be manufactured will, for the present at least, be principally of the kind suitable for domestic use and boiler fuel, there being little or no demand for blast-furnace coke. Probably, however, conditions will be changed extensively by the successful introduction of the new method of working and a market ultimately created for blast-furnace coke, especially in case the duty on iron ore should be removed, which would give Boston and the New England States the proper incentive to produce at least some of the iron and steel they consume. At present most blast-furnace coke is made in beehive ovens, which allow the by-products to go to waste. Only few kinds of coal make satisfactory coke in the beehive, thus restricting it to very small sections, while the by-product oven permits the use of a great variety of coal, and can be erected wherever coking coals occur. If it can produce illuminating gas, heating gas, and coke, varying with the character of the coal, there would seem to be no limit to its probable future usefulness in all parts of the country.

The great importance of the subject has led to the following outline, made with the knowledge of all parties concerned, of the work done at Halifax by the People's Light and Heat Company, and of the preliminary large-scale experiments made for the New England Gas and Coke Company at Glassport, Pennsylvania, with the coal that is to be used in the new Boston plant.

The People's Light and Heat Company at Halifax undertook the manufacture of illuminating gas for the city in March, 1897. They erected a Slocum[1] by-product coke oven. This furnace embodied a number of new ideas aiming to combine the advantages of the ovens of Hüssener[2] and of Semet-Solvay,[3] but it soon proved a failure and was remodeled according to the Semet-Solvay system. It has since been doing satisfactory work. A very interesting experience occurred in connection with the thickness of the partition walls supporting the

[1] See J. Fulton, *Coke.* Scranton, Pa., 1895. p. 215.

[2] *Stahl und Eisen*, 1883, p. 397.

[3] *Engineering and Mining Journal*, August 9, 1890.

roof. In the original Semet-Solvay they were 16 inches thick, in the modified oven 30 inches, which proved a permanent improvement in equalizing the temperature. The material first used was red brick, which had to be replaced by fire brick.

The plant consists of one block of 10 ovens, each being 30 feet long, 5 feet 6 inches high, and from 16 to 17 inches wide, and having 3 charging ports and 2 gas-collecting openings, and the necessary apparatus for condensing and extracting the tar and ammonia and for purifying the gas. An oven is charged with 5 net tons of coal, which is coked in 20 hours. It takes $2\frac{1}{2}$ hours to discharge the 10 ovens, and the same time to refill them, the latter work not being begun until they are all discharged. The time between the charging and refilling of the oven is given to heating up, so as to begin coking with a strong initial heat. The gas pressure in the ovens is kept at $\frac{1}{2}$ inch of water above the atmosphere, so as to prevent any air from entering, which would consume fuel and dilute the gases with nitrogen and carbon dioxide. The temperature in the ovens ranges from 1,800 to 2,000 degrees F.

The coal used is a mixture of washed slack from the International and Phelan seams of the mines of the Dominion Coal Company, Cape Breton. The coal charged contains approximately 60 per cent. fixed carbon.

The gas set free in the ovens is stored in two different sets of holders. All the gas above 16 candle power (measured by a Jones jet-photometer) goes to the illuminating-gas holders; as soon as it sinks below this figure it goes to the heating-gas holders. The illuminating gas, averaging 18 candle power, is supplied at $1.40, the heating gas, averaging $8\frac{1}{2}$ candle power, at $0.40 per 1,000 cubic feet. In 24 hours 37 short tons of coal is coked, furnishing 310,000 cubic feet of gas, of which 100,000 cubic feet (32.26 per cent.) is illuminating gas, and 210,000 cubic feet (67.74 per cent.) heating gas; of this 170,000 cubic feet (54.84 per cent.) is consumed in coking, leaving 40,000 cubic feet to be used as heating gas. A long ton furnishes on the average 5 pounds of ammonia gas and 12 U. S. gallons, 120 pounds, of tar. The ammonia liquor is distilled with milk of lime, and furnishes a shipping ammonia liquor with 17 per cent. ammonia. The tar is utilized in the summer in the manufacture of tar paper; in winter it is distilled, furnishing creosote, pitch, etc. Lastly, the commercial coke, forming 75 per cent. of the coal charged, is broken and

sold at the rate of $4 a ton for domestic purposes and as boiler fuel, the price for anthracite being $4.25 a ton.[1]

This brief outline gives the leading technical results obtained so far. No doubt they will be improved upon by the time the normal method of working is reached, as, of course the first consideration must be to furnish regularly sufficient gas of a required candle power. Experiments in the direction of improvement can only be entered upon very gradually, so as not to interfere with the main product. The best ultimate method of working will depend to a considerable extent on the market for the two leading minor products, heating gas and coke. It may come to this, that with a larger demand for heating gas, the ovens will be heated with producer gas, and even some of the small coke burned in the producers, or stress may have to be laid on making a firmer coke in case a market for blast-furnace coke should open.

The working tests of the New England Gas and Coke Company for the new plant near Boston were made early in the present year at the works of the United Coke and Gas Company, Glassport, Pennsylvania, where the Otto-Hoffmann by-product oven is in operation, which is the one decided upon for the Boston plant. They were carried out by Dr. F. Schniewind with washed slack coal from the mines of the Dominion Coal Company, Cape Breton.

The works at Glassport were erected in 1896. They have four blocks of furnaces, each with 30 ovens. Each oven is 33 feet long, 5 feet 10 inches high and $20\frac{3}{4}$ inches wide. The coal usually treated is the run-of-mine of the Washington Coal and Coke Company's mine, on the upper Youghiogheny River, and has the following composition:

Moisture,	Fixed carbon,	Volatile matter,	Ash,	Total,
0.60	59.18	33.01	7.21	100.00.

Phosphorus, 0.0071; Total sulphur, 1.27; (fixed, 0.80; volatile, 0.47.)

A charge of $6\frac{1}{4}$ gross tons dry coal is coked in 34 hours 54 minutes, and yields 74.26 per cent. salable coke, the coke having the composition:

Volatile matter,	Fixed carbon,	Ash,	Moisture,	Total,
1.00	86.47	11.57	3.17	100.00

Sulphur, 0.96; Phosphorus, 0.0107.

is used in the iron blast furnace. A net ton of coal furnishes 10,000

[1] The record for the month of September shows an improvement on that of June given above. With nine ovens working, 1,416 net tons of coal were coked, which gave 12,889,900 cubic feet of gas, or 9,060 cubic feet per net ton of coal; of this 45 per cent. was surplus gas.

cubic feet of gas, of which 70 per cent. is required to heat the ovens, the rest piped $1\frac{1}{2}$ miles to steel works for heating an open-hearth furnace. The other products are 5.27 per cent. tar and 1.230 per cent. sulphate of ammonia.

The tests were carried out in one of the ovens, the rest of the block being in use at the same time for their regular purpose, thus having actual working conditions. Of course, the oven was heated by the surplus gas from the ovens of the block. By measuring the volume of the gas used and determining its calorific power, the heat consumed by the oven is easily arrived at. The volatile compounds of the test-oven were collected in a separate main and examined as to quality and quantity, and the coke produced was kept apart from that of the other ovens. In all, 143 tons of coal from three different seams were coked. Of this, only the work on 40 tons of washed slack from the International seam will be discussed.

The Coal. — As charged into the oven the coal contained 9.9 per cent. of water, this high figure being due to the coal having been exposed for several months to rain and snow. The hygroscopicity of the coal was determined at 4.01 per cent., so that under normal conditions the coal will not contain over 5 per cent. of water. An average of several ultimate analyses gave the composition :

C,	H,	N,	O + S,	Ash,	Total,
75.10	3.75	1.51	13.80	5.84	100.00.

and one of several proximate analyses :

V. H-C.	F. C.	Ash,	Total,
34.60	59.56	5.84	100.00.

It will be noted that sulphur and oxygen are given as a total of 13.80 per cent., which is unusual. In the destructive distillation of coal, sulphur has a harmful effect on the gas as well as on the coke, especially if the latter be used in the production of pig iron. From the gas it can be readily eliminated by an increased purification plant; from the coke the matter is more difficult. A great number of sulphur determinations have been made from the coal that is to be used. Instead of giving a mass of figures it will be better simply to tell what is being done at present with Cape Breton coal. It is supplied to the amount of 200 tons per day to the iron blast-furnace plant of the Nova Scotia Steel Company, at Ferrona, Nova Scotia, which uses it exclusively for the manufacture of its coke. The percentage of sul-

phur in the coal varies considerably; while in some parts of the bed it may occasionally reach 3 per cent., in others it is only a few tenths of 1 per cent., and on the average the percentage of sulphur is low. The coke made at Ferrona from unwashed Dominion coal contains as impurities 1.08 per cent. of sulphur and 8.20 per cent. of ash. Coals running higher in sulphur are first washed in the plant erected by Mr. W. M. Stein,[1] of Philadelphia, before they are coked. The iron ore used by the company comes in part from its own mines in the neighborhood, in part from Newfoundland.

Both basic pig and foundry iron are produced as seen in the following analyses:

Kind.	Si.	Mn.	P.	S.	G. C.	C. C.
Basic pig	0.50	0.87	1.23	0.017	....	....
Foundry iron	2.32	0.65	1.20	0.020	3.64	0.23

The percentage of phosphorus in the average coke analysis is exceptionally low, viz., 0.0028 per cent. The calorific power of the dry fuel with 5.84 per cent. of ash calculated according to the Dulong-Mahler formula, is 12,437 B. T. U. The coal is a good coking coal and has the advantage that the finished coke occupies a smaller space than the coal.

The Operation. — In coking, the average weight of the four charges was 14,591 pounds of coal, which, deducting the moisture (1,348 pounds), corresponded to 13,602 pounds of dry coal. The average time required for complete destructive distillation was 33 hours 56 minutes, or 5 hours 35 minutes per long ton of dry coal. The regular working time for slack of the Youghiogheny mine with 1 per cent. of water is 5 hours 26 minutes. This proves that International coal compares favorably with it. With dryer coal the showing will be still better. By using an oven 18 inches wide instead of $20\frac{3}{4}$ inches, the coking time can be reduced to 26 hours, and if the coke is to be used only for domestic purposes or as boiler fuel instead of for the blast furnace, like the Glassport coke, the time required will be only 22 hours, and 24 hours will be a safe figure. The range of temperature in the four tests, measured by the Mesuré and Nouel optical pyrometer, was from 950 to 1,070° C. In a general way it is known that a high temperature increases the quantity, but diminishes the quality of the gas obtained, but the differences in temperature

[1] See Fulton, *Coke*. Scranton, Pa., 1895, p. 67.

were not sufficient to have any decided influence on the composition and candle power of the gas.

SUMMARY OF RESULTS. — A summary of the results obtained per long ton of coal, the volumes having been reduced to weights, is subjoined:

Products from 1 long ton of coal.	Pounds.	Per cent.
Coke, total { Large coke, > 1″, 66.69 per cent. / Small coke, ½ — 1″, 1.64 per cent. / Breeze, < ½″, 2.80 per cent. }	1,593.4	71.13
Tar	75.7	3.38
Ammonia (= 1.373 per cent. sulphate)	7.6	0.34
Gas, total, 10,390 cubic feet, of 0.466 specific gravity	368.0	16.43
Sulphur compounds in gas:		
Hydrogen sulphide (H_2S), 0.98 pounds per 1,000 cubic feet	10.8	0.48
Carbon disulphide (CS_2), 0.13 pounds per 1,000 cubic feet	1.6	0.07
Gas liquor and loss, by difference	182.9	8.17
Total	2,240.0	100.00

Of the 10,390 cubic feet of gas, 49.5 per cent. was surplus gas, that is, gas not required for the heating of the oven. This had the following composition:

Olefines, CmHn,	5.2,	Marsh gas, CH_4,	38.7,	Hydrogen, H_2,	38.4,
Carbon monoxide, CO,	6.1,	Carbon dioxide, CO_2,	3.6,	Oxygen, O_2,	0.3,
Nitrogen, N_2,	7.7,	Total,	100.0.		

Its calorific power (H_2 burnt to liquid water) was 686 B. T. U., its candle power 14.7, and its specific gravity (air = 1) 0.510.

COKE. — The yield of dry coke, as shown above, was 71.13 per cent. After quenching and cooling it retained 3.67 per cent. of moisture, hence the figure 71.13 is increased to 73.91 per cent. As only the large and small coke are the marketable products, the salable coke will amount to 68.33 per cent. of the coal, or with the usual 2 per cent. of water of commercial retort coke, 69.70 per cent. of commercial coke. Most of the coke was what may be called a fair metallurgical fuel. It was hard, had a good cellular structure, a metallic ring and a silvery luster. Its composition is shown by the following approximate analysis:

Volatile matter,	Fixed carb. and S,	Ash,	Total,
1.27	69.82	8.91	100.00,

P.,	Moisture,
0.0041	3.67.

Regarding sulphur see above. The low percentage of volatile matter proves that the destructive distillation was complete. The subjoined analysis of the coke ash,

SiO_2,	Al_2O_3,	F_2O_3,	Mn_3O_4,	CaO,	MgO,
27.71	13.04	50.60	0.25	4.61	0.77

K_2O,	Na_2O,	SO_3,	P_2O_5,	Total,
0.85	0.18	2.62	0.10	100.73,

shows a high percentage of iron and small amounts only of alkali. The iron, due mainly to pyrite in the coal, can be greatly diminished, and, assuming it to be completely eliminated, the analysis will be changed to

SiO_2,	Al_2O_3,	Mn_3O_4,	CaO,	MgO,
55.29	26.01	0.50	9.19	1.53

K_2O,	Na_2O,	SO_3,	P_2O_5,	Total,
1.70	0.36	5.22	0.20	100.00,

giving a total of 2.06 per cent. of alkali. Such an ash is not liable to form clinkers on the grate.

TAR. — The yield of tar was 75.7 pounds per long ton of coal, or 3.38 per cent.; its specific gravity was 1.170. The following table shows its behavior in fractional distillation as well as that from the Otto-Hoffmann oven at the Germania plant, and from German gas works:

Fractions.	Temperature, C°.	Otto-Hoffmann oven.		Average German gas-house tar.	
		International coal.	Germania plant.	I.	II.
Light oil	80—170	3.7	6.55	3.0	2.5
Middle oil	170—230	9.8	10.54	7.5	2.5
Heavy oil	230—270	12.0	7.62	33.5	25.0
Anthracene oil . . .	over 270	4.3 } 71.3	44.35 } 74.9	10.5 } 56.0	10 0 } 70.0
Pitch	.....	67.0 }	30.55 }	45.5 }	60.0 }
Water	.....	2.3	Trace.	.....	.....
Loss	.....	0.9	0.39	.....	.....
Total	.....	100.00	100.00	100.00	100.00
Specific gravity . .	.....	1.170	1.1198	1.155	1.155

The softening point of the pitch was 87 degrees C., and its specific gravity 1,350. There is considerable difference between the ratio of

anthracene oil and pitch in the two tars of the Otto-Hoffmann oven. The reason for this is that with the Germania tar the distillation was carried on until all the vapors had been expelled. The softening point of the pitch was therefore much higher, viz., 165 degrees C. The table shows that the tar from the tests compares favorably with that from other sources. It has been thought that tar from by-product coking ovens was inferior in quality to that from retorts of gas works. The following is a comparative table[1] of tar analyses from gas works and from an Otto-Hoffmann plant using the same kind of Westphalian coal.

Fractions.	Gas-house tar.	Otto-Hoffmann coke-oven tar.
Water	2.9	2.2
Light oils to 200° C.	4.0	3.4
Aniline benzole	0.92	1.1
Solvent naphtha	0.20	0.32
Creosote oil	8.6	14.5
Crude naphthalene	7.4	6.7
Anthracene oil	17.4	27.3
Pure anthracene	0.6	0.7
Pitch	58.4	44.4
Totals	100.42	100.62
Free carbon in pitch	15—25	5—8

It shows that the coke-oven tar is better for the purposes of the tar distiller than gas-house tar. The yield of tar ($3\frac{3}{8}$ per cent.) is, however, low in comparison with that from gas works, which obtain about 5 per cent. The distillation of tar may be of importance with regard to the recovering of benzole as enriching material.

Ammonia. — The gas-liquor obtained was 182.9 pounds per long ton of dry coal or 8.17 per cent., containing 7.6 pounds or 0.34 per cent. of ammonia. Tests showed that 96.6 per cent. was present as free, or volatile, ammonia, *i. e.*, ammonia that can be recovered by simple distillation; and only 3.4 per cent. was fixed ammonia, that is,

[1] Lunge, *The Mineral Industry*, V., p. 188.

ammonia in chemical combination as sulphate, chloride, rhodanate, etc., which can be recovered only by the addition of lime in the distillation. As the ultimate analysis given above shows 1.51 per cent. of nitrogen in the coal, and the 0.34 per cent. of ammonia requires 0.28 of nitrogen, it will be seen that 18.5 per cent. of the total nitrogen of the coal is converted into ammonia, which is a good showing, as usually only 13½ to 15 per cent. is thus changed.

Gas. — The total volume of gas per long ton of dry coal collected in the holders was 10,390 cubic feet. At the time when the tests were made the average temperature of the air was 37 degrees F., and the barometer showed a pressure of 750 millimeters. As the normal temperature for calculations is 60 degrees F., the volume of gas would be 4.7 per cent. less than under normal conditions. This is partly offset by the low atmospheric pressure, the normal being 760 millimeters; the volume, however, remains 3.2 per cent. less than when reduced to 60 degrees F. and 760 millimeters pressure. The error is so slight as to make a correction unnecessary, The samples for analysis were taken between the exhauster and the scrubber entrance and passed through a small iron-oxide purifier. A complete analysis was made about every 2 hours; the specific gravity was determined hourly as well as the calorific power and the candle power. Sulphur tests of the unpurified gas were made continuously, but only during the first 12 hours after charging.

Diagram 1 is a graphical representation of the average analysis of the gases from the four separate charges.

The percentage of marsh-gas (CH_4) shows a rapid decline, and this is especially the case toward the end of the coking operation. It is accompanied by a corresponding increase of hydrogen (H), which reaches nearly 67 per cent., or nearly 80 per cent. if figured for gas free from oxygen and nitrogen. The curve of carbon monoxide (CO) shows the percentage of this gas to vary between the narrow limits of 5.4 and 6.8 per cent., a very low figure. The olefines (CmHn) remain at a constant figure, 6½ per cent. for the first 5 hours, and then diminish at a uniform ratio to the end of the operation. The percentage of carbon dioxide (CO_2) is constant for the first 20 hours, ranging at from 3 to 4 per cent., and then decreases gradually to 1 per cent. Oxygen (O) and nitrogen (N) are accidental impurities. The oxygen gets into the gas through leaky joints and amounts to about 0.3 per cent. The average percentage of nitrogen during the first 14 hours and 46 min-

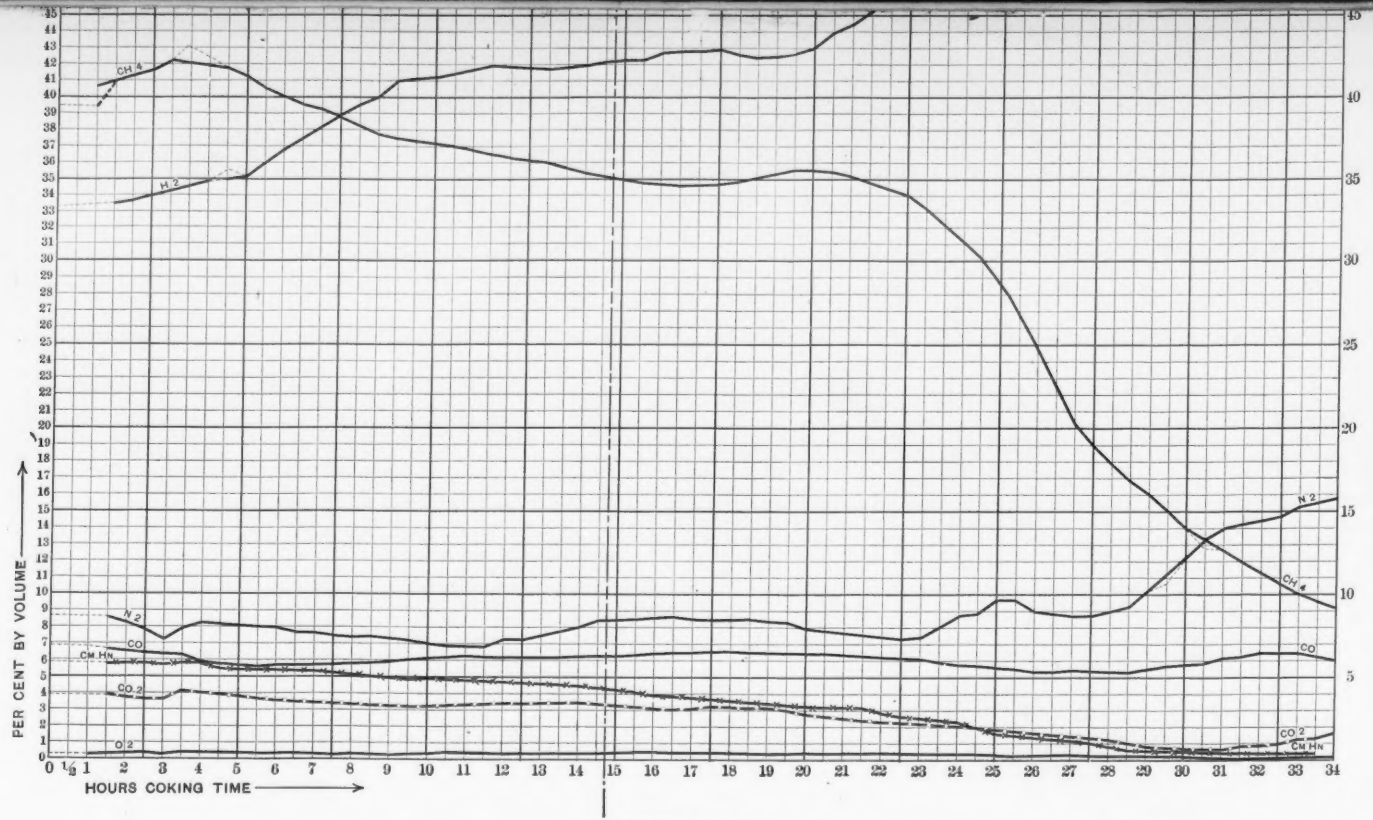


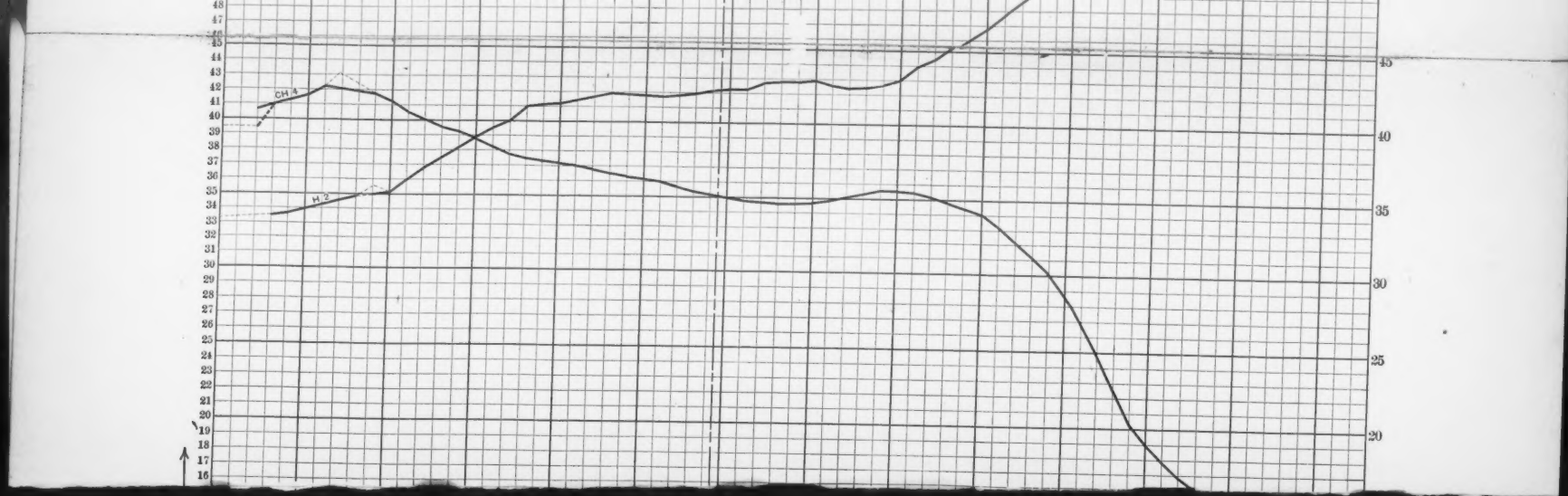
DIAGRAM NO. 1.

Surplus gas produced during the first 14 hours, 46 minutes. Volume per long ton, 5,143 cu. ft. = 49.5 per cent. Average analysis:

C_mH_n	CH_4	H_2	CO	CO_2	O_2	N_2	Total.
5.2	38.7	38.4	6.1	3.6	0.3	7.7	100.0

Oven-heating gas produced during the remaining 19 hours, 10 minutes. Volume per long ton, 5,247 cu. ft. = 50.5 per cent. Average analysis:

C_mH_n	CH_4	H_2	CO	CO_2	O_2	N_2	Total.
2.4	29.2	50.5	6.3	2.2	0 3	9.1	100.0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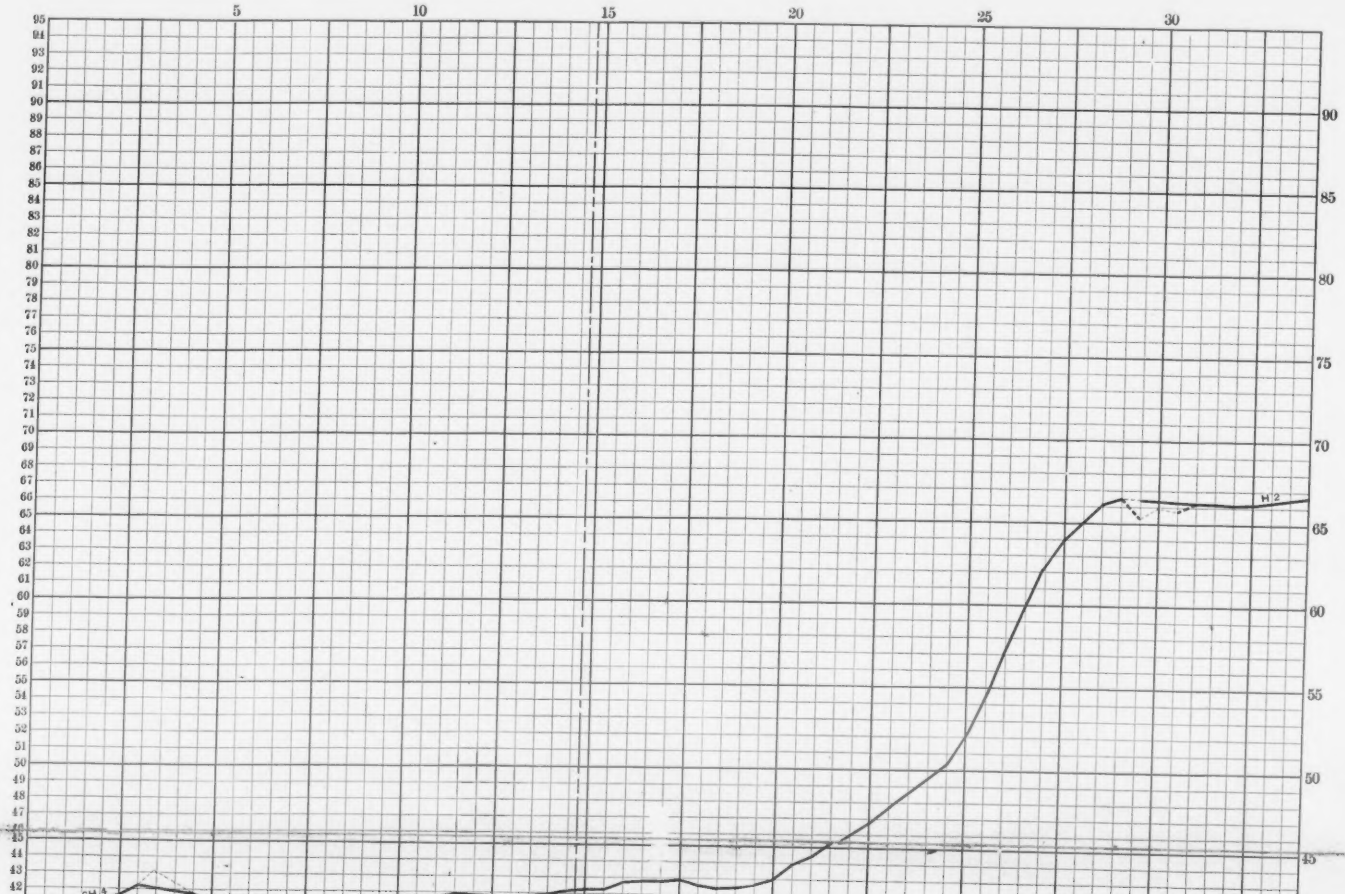
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utes is seen to be 7.7 per cent.; that of the last 19 hours and 10 minutes, 9.1 per cent. It remains pretty constant up to the 23d hour, and then increases rapidly. It has its origin in the destructive distillation, which accounts for 2–3 volumes, and in leakages which permit the entrance of air. The large increase toward the end finds its explanation in the diminished volume of gas generated in the oven and the consequent decrease of pressure. The percentage of nitrogen is high, and will under normal working conditions be reduced to 5 per cent.

Diagram 2 is a chart, the curves of which give the calorific power, the specific gravity, and the candle power of the gas. Disregarding a slight irregularity in the curves during the first two to three hours, due to the fact that the last portions of gas from a preceding experiment become mixed with the first gas of the following one, the calorific power at the beginning is about 685 B. T. U. It rises quickly to 775 B. T. U., then drops quickly until the 7th hour, and more slowly until the 22d hour, after which it drops more quickly than at first until the end of the operation.

The curve of the specific gravity runs almost parallel to that of the calorific power, only that the drop is not quite so rapid. Toward the end the specific gravity is slightly higher, which is due to the increase in the percentage of nitrogen. The candle power is seen to drop rapidly during the first 7 hours, then slowly to the 24th hour, when the decline is again very rapid, so that toward the end the gas has no illuminating value whatever.

Diagram 3 gives a graphical representation of the total volume of the gas obtained from 1 long ton of dry coal, its calorific power, and the relation of this to the total amount of heat required for coking. The volume of gas obtained is seen to remain almost c[illegible]t during the first 24 hours; in the 22d and 23d hours there is an increase in volume, followed by a rapid decline. The increase is due to the last thin layer of coal in the centre of the oven being heated from both sides instead of only from one side, as was the case up to that time, the coal having received its heat chiefly from the side wall contiguous to it. The sudden drop is explained, of course, by the fact that the last of the coal having been heated to the coking temperature, the volume of gas liberated diminished very quickly.

The heat value of the gas is seen to keep pace pretty evenly with the vol[illegible]e. Diagrams 1, 2, and 3 give all the information required

about the composition, the important physical properties, and the volume of the gas produced during the entire process. Combining the results of the three diagrams, three periods in the process can be distinguished.

The first period, lasting 9 hours, is one of declining value of gas. The percentage of marsh gas diminishes; that of hydrogen grows; the calorific power is reduced from 775 to 685 B. T. U.; the specific gravity drops from 0.550 to 0.490 and the candle power from 18 to $13\frac{1}{2}$. The second period, reaching from the 9th to the 22d hour, produces gas of almost constant quality. The percentages of marsh gas and hydrogen are very little changed; the calorific power, specific gravity, and candle power are pretty constant.

The third period is again one of declining value of gas. The percentage of marsh gas diminishes rapidly, with a corresponding increase in hydrogen; the calorific power, specific gravity, and candle power show a rapid decline.

The decrease in volume is very gradual up to the 22d hour, when (for reasons given above) there is a small increase in the 23d hour which is followed by a rapid decline.

The gas of the first period, after purification, can be advantageously used for illuminating purposes; that of the second period for heating the ovens, and that of the third period, after having been purified and enriched with benzole or oil vapors, or with oil gas, can be mixed with that from the first period. This last gas, being so rich in hydrogen, is especially adapted to serve as a carrier of hydrocarbon vapors.

Heating with Oven Gas. — A question still to be settled is, How much of the gas is required to heat the ovens? It was stated at the beginning that the test oven had been heated with the gas from the other 29 ovens of the block. The amount of gas required per charge of 13,602 pounds dry coal was 36,169 cubic feet. As its calorific power was 499.2 B. T. U., the amount of heat required was $36{,}169 \times 499.2 = 1{,}805{,}564$ B. T. U. The heat consumption of 1 long ton for the entire coking time (33 hours, 55 minutes) was therefore 2,973,680 B. T. U., or of 1 long ton for 1 hour, 87,633 B. T. U., further the heat consumption per oven per hour, 532,090 B. T. U. This is graphically represented in Diagram 3 by the shaded area. This figure show sthat up to and including the 29th hour the heat value of the gas produced is greater than that required for coking, but after

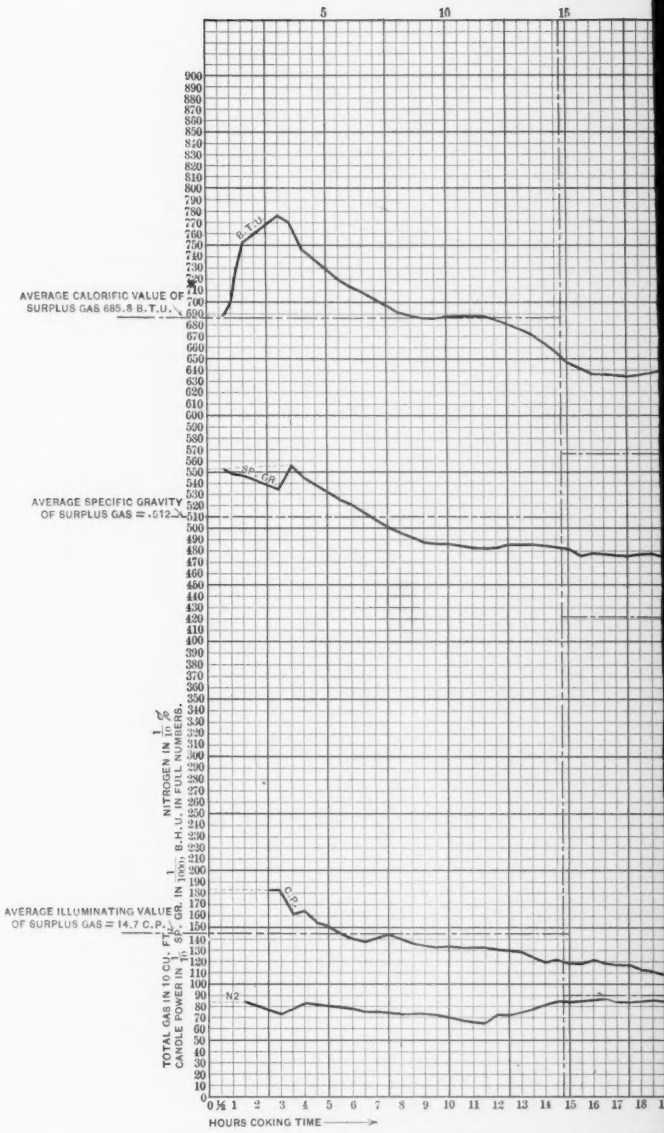
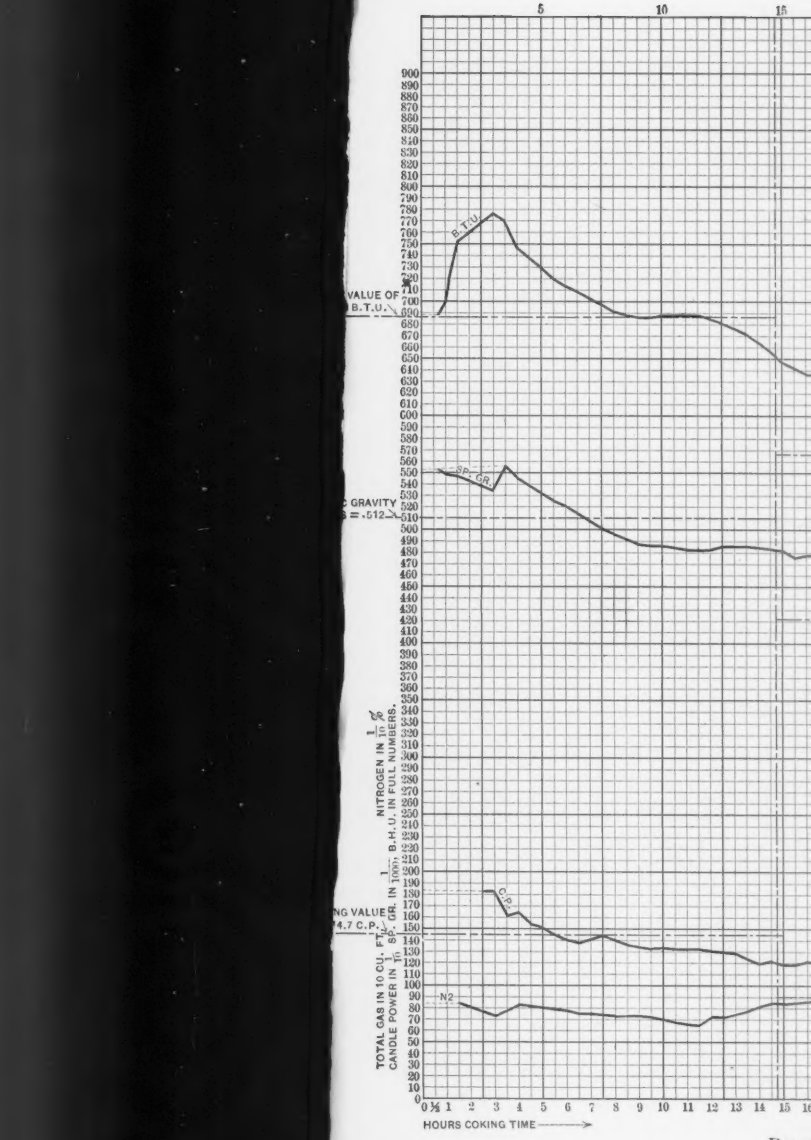

AVERAGE CALORIFIC VALUE OF SURPLUS GAS 685.8 B.T.U.
AVERAGE SPECIFIC GRAVITY OF SURPLUS GAS = .512
AVERAGE ILLUMINATING VALUE OF SURPLUS GAS = 14.7 C.P.
B.T.U.
SP. GR.
C.P.
N2
TOTAL GAS IN 10 CU. FT. 1
CANDLE POWER IN 10 SP. GR. IN 100, B.H.U. IN FULL NUMBERS. 1
NITROGEN IN 1 %
HOURS COKING TIME

DIAGRAM No

Ove

Surplus gas produced during first 14 hours, 46 minutes:

Average calorific value	685.8 B. T. U.
Average illuminating value	14.7 C. P.
Average specific gravity value	.512
Volume per long ton, 5,143 cubic feet = ...	49.5 per cent.



DIAG

roduced during first 14 hours, 46 minutes:

calorific value	685.8 B. T. U
illuminating value	14.7 C.
specific gravity value	.5
per long ton, 5,143 cubic feet =	49.5 per cent

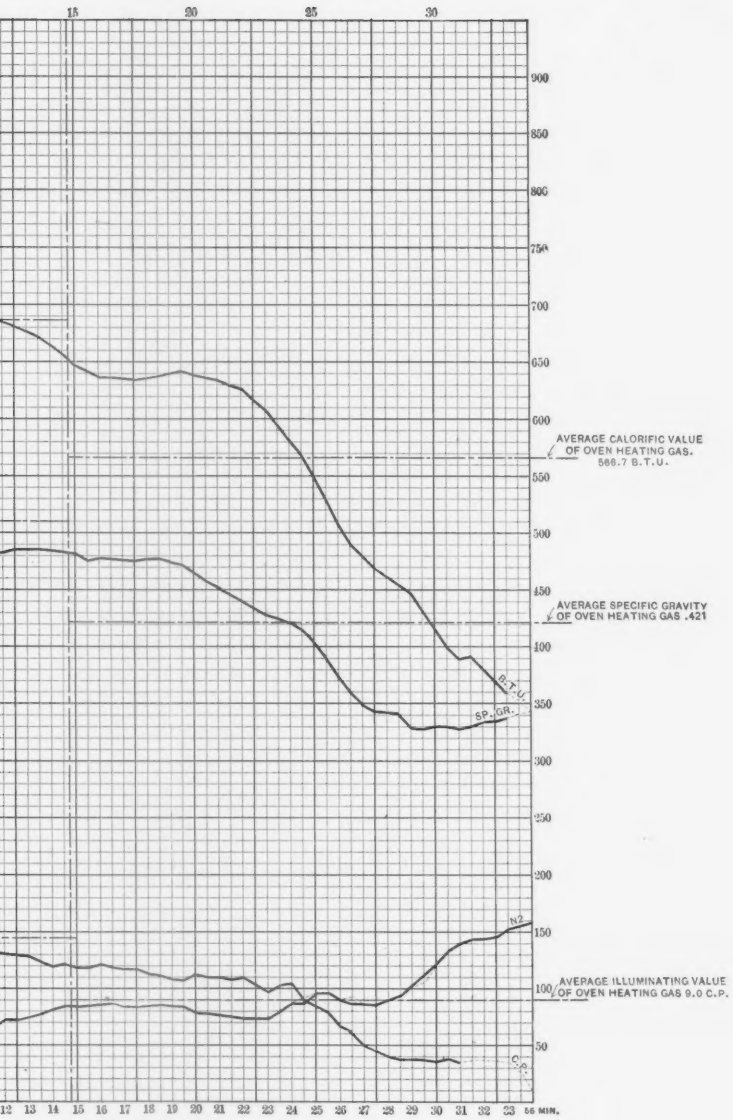


DIAGRAM NO. 2.

	Oven-heating gas produced during remaining 19 hours, 10 minutes:	
585.8 B. T. U.	Average calorific value	566.7 B. T. U.
14.7 C. P.	Average illuminating value	9.0 C. P.
.512	Average specific gravity value	.421
49.5 per cent.	Volume per long ton, 5,247 cubic feet	50.5 per cent.

that time there is a lack of heat which would have to be supplied in case the ovens were exclusively heated by coke-oven gas and blast-furnace coke was to be produced. If the coke is to be used for domestic purposes or as a boiler fuel, a softer coke is more desirable and the coking can be advantageously interrupted at the 29th hour and the amount of gas represented by the area *A B C* saved. With ovens 18 inches wide instead of $20\frac{3}{4}$ inches, this can be done still sooner.

Above, three periods have been distinguished in the process of coking, furnishing three different kinds of gas. In practice it simplifies the arrangement of the parts of the plant to divide the gas produced into two parts, the first, richer in marsh gas, to be surplus or illuminating; the second, the heating gas, as is done at present at Halifax. The question is, Where must the line be drawn? The total gas produced per long ton of coal was found to be 1 390 cubic feet, having a heat value of 6,501,000 B. T. U. In order to coke 1 long ton of coal 2,973,680 B. T. U. were necessary; that is, the heat value of the gas produced in the last 19 hours and 10 minutes, leaving 14 hours and 46 minutes for surplus or available illuminating gas. This line of division is shown in the three diagrams. The data tabulated give the following heat balance:

Per long ton dry coal.	Volume.		Calorific Power.	
	Cubic feet.	Per cent.	B. T. U.	Per cent.
Gas used for heating oven	5,247	50.5	2,973,680	45.8
Surplus gas	5,143	49.5	3,527,320	54.2
Total gas consumed	10,390	100.0	6,501,000	100.0

The difference in calorific power, candle power, and specific gravity of the two gases is shown by the following table:

Per long ton dry coal.	Volume. (Cubic feet.)	Calorific power. (B. T. U.)	Candle power. (C. P.)	Specific gravity. (Air = 1.)
Surplus gas, 1st fraction	5,143	685.8	14.7	0.512
Oven heating gas, 2d fraction . .	5,247	366.7	9.0	0.412
Average of entire gas produced .	10,390	626.0	11.6	0.466

Finally, the difference in chemical composition is shown by the following analyses:

	Cm Hn	CH_4	H_2	CO	CO_2	O_2	N_2	Total.
Surplus gas, 1st fraction . . .	5.2	38.7	38.4	6.1	3.6	0.3	7.7	100.0
Oven heating gas, 2d fraction .	2.4	29.2	50.5	6.3	2.2	0.3	9.1	100.0
Average of entire gas produced .	3.8	33.9	44.5	6.2	2.9	0.3	8.4	100.0

The calculation of the volume of surplus gas has been based upon dry coal, while the coals tested contained 9.9 per cent. of water. This is equivalent to 222 pounds of water per long ton of coal. The heat required to bring 222 pounds of water from 60° F. to 212° F. is 33,744 B. T. U., and that required to convert 222 pounds of water having a temperature of 212° F. into steam of 212° F. is 214,452 B. T. U., which gives a total of 248,196 B. T. U. Leaving out the amount of heat required to raise the steam of 212° F. to the temperature of the gases of the gas-escape pipe from the ovens, the heat required for evaporation of the water is equivalent to 8.3 per cent. of the total heat required for coking 1 long ton of coal, or 2,973,680 B. T. U. This shows the importance of obtaining the coal in a drier state. Five per cent. may serve as an average figure. This decrease of water will give more surplus gas and shorten the coking time.

Heating with Producer Gas. — The amount of gas consumed by a city at different periods varies greatly. In making gas in small retorts a larger or smaller number can be put into operation, or the fires heating them can be urged in a greater or less degree. A by-product coking oven, however, has to run uniformly all the year round, which means producing the same amount of gas. If heated exclusively with its own gas it would not be well adapted for furnishing greatly varying amounts of illuminating gas. When the consumption is small the excess of the surplus gas would have to be disposed of at any price it could bring, or go to waste. In order to make the system elastic, the ovens will have to be heated by some other fuel than coke-oven gas during the period of greatest consumption of illuminating gas, and this fuel will be found in producer gas. In times when the consumption of illuminating gas is greatest the ovens will be heated exclusively with producer gas, and the whole coke-oven gas converted

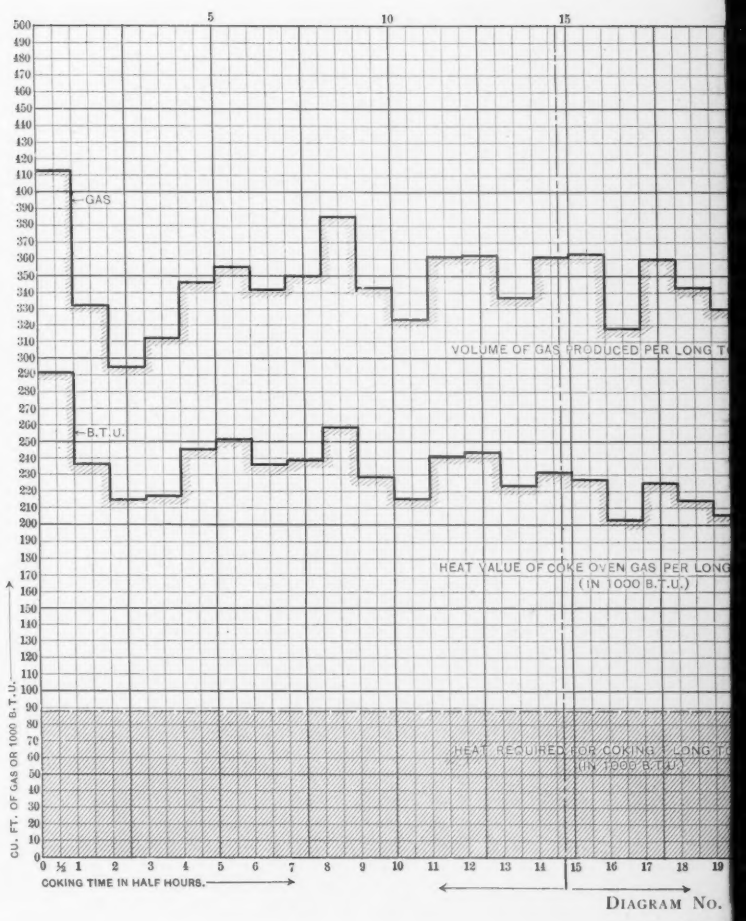

GAS
B.T.U.
VOLUME OF GAS PRODUCED PER LONG T
HEAT VALUE OF COKE OVEN GAS PER LONG
(IN 1000 B.T.U.)
HEAT REQUIRED FOR COKING 1 LONG T
(IN 1000 B.T.U.)
CU. FT. OF GAS OR 1000 B.T.U.
COKING TIME IN HALF HOURS.

DIAGRAM NO.

Volume

Surplus gas produced during first 14 hours, 46 minutes: 5,143 cu.

Surplus gas produced during remaining 19 hours, 10 minutes: 5,247 cu.

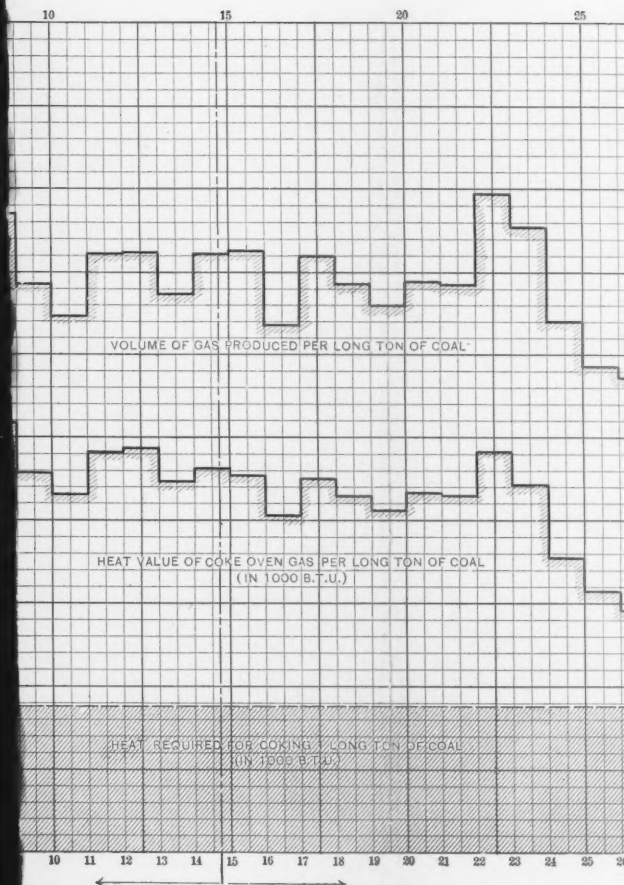
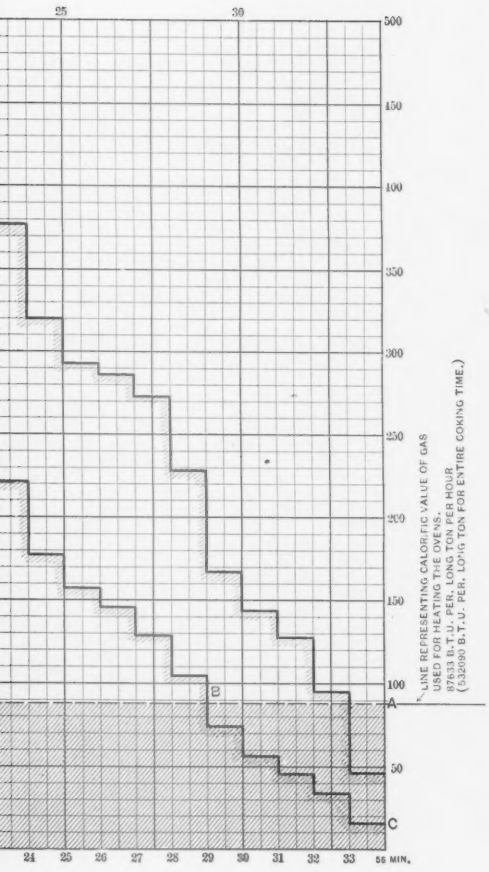

10
15
20
25
VOLUME OF GAS PRODUCED PER LONG TON OF COAL
HEAT VALUE OF COKE OVEN GAS PER LONG TON OF COAL
(IN 1000 B.T.U.)
HEAT REQUIRED FOR COKING 1 LONG TON OF COAL
(IN 1000 B.T.U.)
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

DIAGRAM No. 3.

	Volume.	Calori
ng first 14 hours, 46 minutes:	5,143 cu. ft. = 49.5 per cent ;	3,527,3
ng remaining 19 hours, 10 minutes:	5,247 cu. ft. = 50.4 per cent. ;	2,973,68



Calorific value.

ent ; 3,527,320 B. T. U. = 54.2 per cent.
ent. ; 2,973,680 B. T. U. = 45.8 per cent.

into illuminating gas; in times of smallest consumption the ovens will be heated exclusively with coke-oven gas, illuminating gas being produced the first 14 hours of the coking period, heating gas the rest of the time. One net ton of bituminous coal furnishes 130,000 cubic feet of producer gas of a calorific power of 150 B. T. U. This figure comprises only the latent heat of the gas. The larger part of the sensible heat will be lost by freeing the gas from dust and ashes, as it is not advisable to introduce it into the checker-work of the Otto-Hoffmann oven while it still holds these particles in suspension. This loss, however, is not great, as the total heat of the gas being 100, the latent heat forms 82.8 per cent., the sensible heat 7.7 per cent., and the loss by radiation, etc., 9.5 per cent. The coke oven can be, so far as heat values are concerned, successfully heated with producer gas. As to the matter of cost, it is cheaper to heat with producer gas than with that from the coke oven. In regard to the flues and the checker-work, they will have to be larger than the size required for coke-oven gas, as producer gas contains about 60 per cent. of inert nitrogen.

The candle power of the oven gas will be reduced from 14.7 to 11.8 if all of it is collected in one holder. The additional cost of bringing it up again to the standard would more than be covered by the saving from the use of producer gas.

By-Product Coke Oven and Gas House Practice. — In this paper details as to cost have been intentionally omitted as being foreign to its purpose. However, by tracing the original calorific value of the coal through the products of destructive distillation a heat balance can be struck between the proposed production of illuminating gas in the by-product coke oven and the usual practice of gas works.

100 pounds dry coal yields —	B. T. U. (Per lb.)	Total calorific power. (B. T. U.)	Per cent. of calorific power of dry coal.
71.13 pounds coke	12,645	899,456	72.3
3.38 pounds tar	12,210	51,410	4.1
229.6 cubic feet surplus gas	686	157,504	12.7
234.2 cubic feet heating gas	567	132,835	10.7
Ammonia liquor, sulphur in purifier, and loss	.....	2,496	0.2
Total = 100 pounds dry coal	.....	1,243,700	100.0

The heat contained in 100 pounds dry coal is distributed as follows:	Per Cent. of Total Heat Value of Coal.	
	German coal in gas retorts.[1]	International coal in Otto-Hoffmann ovens.
In coke, salable	46.4	72.3
In coke used for heating retorts	10.1	....
In tar	5.5	4.1
In gas, salable	21.0	12.7
In gas for heating ovens	....	10.7
In ammonia liquor, sulphur in purifiers, and loss	17.0	0.2
Total	100.0	100.0
Heat used and lost in distillation process	27.1	10.9
Heat contained in products	72.9	89.1
Total	100.0	100.0

The second table shows that in the coke oven practice 10.7 + 0.2 = 10.9 per cent. of the heat value of the coal is consumed in destructive distillation, while gas house practice requires 10.1 + 17.0 = 27.1 per cent.

Some minor details still remain to be discussed, such as the advantages alluded to above, of the premature pushing of the coke after 29 hours, instead of after 34 hours, when the coking is completely finished, and the disposal of coke breeze (use under boilers with mechanical stokers, manufacture of briquettes, recharging into coking ovens, etc.) — questions having a direct financial bearing rather than one of scientific interest. The purification of coke oven gas from carbon dioxide and sulphur compounds and the enriching it to bring it up to the standard of 20 candle power are matters of daily gas house practice, and need not be dilated upon here.

Conclusion. — The above summary will serve to show that from the standpoint of chemical and thermal analysis the production of illuminating gas in by-product coke ovens is upon a very sound basis, and much could be added to prove that this is equally true from a financial point of view. The data have been obtained from the extensive report of Dr. F. Schniewind, which is a model of its kind.

[1] Oechelhaeuser, W. von. Die Steinkohlen-Gasanstalten als Licht-, Wärme- und Kraftcentralen. Dessau, 1893

THE NORMAL CHLORINE OF THE WATER SUPPLIES OF JAMAICA.

By ELLEN H. RICHARDS, A. M., and ARTHUR T. HOPKINS, S. B.

Read March 10, 1898.

Jamaica, the leading English possession in the West Indies, lies 90 miles south of Cuba, and 100 miles west of San Domingo, or Hayti. Its somewhat irregular oval outline is 144 miles in length by 49 miles in width. It has an area of 4,190 square miles, or somewhat over two and a half million acres, rather less than one-sixth of this being arable, level land. This statement impresses one with the extent of the mountainous area of the island. One principal chain of mountains extends, under various names, the whole length of the island from east to west, and its numerous lateral branches, extending generally in a northerly and southerly direction, very effectually divide the land into hills and deep, narrow valleys. The island appears to be of an igneous formation, but is for the most part deeply overlaid with limestone. There are three extensive alluvial plains, all on the southerly side: that of the Black River district in the southwest; the extensive Liguanean Plain, on which Kingston and Spanishtown are situated, in the south; and the Plantain Garden River district in the southeast, containing the richest banana soil of the island. This Plantain Garden River valley will have a peculiar interest to us later. It is noticeable also, that while the outlines of the mountains and of the coast are bold and rugged on the northerly side, the mountains of the southerly side are more rounded and sloping, the shores gentle and shelving, and the rivers frequently end in swampy lagoons with the various formations that accompany undisturbed sedimentation.

Let us consider the factor which with the mountainous backbone determines the meteorology and climate of Jamaica, the trade winds. These winds are the "northeast trades," so called, and during the day from 9 to 5 o'clock their force and direction are very constant, being almost never interrupted, except by storms. The moisture-laden air of the Carribean Sea is driven forcibly against the hills and mountains of the eastern and northern shores; the vapor is condensed and abun-

dant showers result; how abundant is indicated by the estimated rainfall for Port Antonio in 1891, nearly 200 inches, with an average for the entire island of about 70 inches. A curious variation from this rule is met with in the wind and rainfall of the Plantain Garden River district, which come from the *southeast.* A certain quantity of rain clouds come over the mountains and through Cuna Cuna Pass, but most of the rain comes from the undischarged "northeast trades" which are actually deflected by the John Crow Range into a southeasterly direction. The deflected moist air striking the cool mountain sides north and west of Bath gives up much of its rain to this district, and then passes on towards Kingston as a comparatively dry "southeast trade" wind.

As a result, then, of the topography of the country and of its position in the path of the trade winds, the eastern and northern sections have an abundant rainfall; numerous mountain torrents and rivers, small and large, which change their depth and volume with almost every shower, and a most luxuriant and tropical vegetation. It is here, therefore, that the most varied and beautiful scenery is found; here that the fruit plantations are most abundant and successful; and here that sanitary problems are perhaps most interesting and fruitful. On the other hand, the Manchester and Santa Cruz Mountains in the southwest, with their elevation of three or four thousand feet, their New England-like scenery and cool, dry atmosphere, have a world-wide reputation as health resorts for the cure of pulmonary diseases; while for those who desire a hot, dry climate there is the entire middle section, south of the central range, from Porus in the west to Yallahs River in the east. This portion is comparatively dry, except during the rainy seasons. Many of the rivers indicated on the map are nearly or quite evaporated during the dry season, obliging the inhabitants to rely largely for their water supply on vast cisterns, with the help of a few rivers which break through the mountain; or, as in the case of Kingston, to tunnel through the mountain and tap the Agualta River. The variety of climate is convenient for the tourist, as it allows for a complete change within a few miles; for the inhabitant it is less so, as his residence is usually fixed, by the exigencies of his occupation, within very narrow limits.

The peculiar topography of the country has another effect. On the north it limits the location of the important towns to the coast, not only on account of the heavy rains which seriously affect moun-

tain roads, but also from the direction and the precipitous character of the mountain ranges, which force the lines of travel into the valleys, which here are usually at right angles to the coast; while in the south and west the towns are located away from the coast and on the inland plains and plateaus.

The soil is very rich, and usually of great depth in the valleys where it has accumulated from the constant scouring of the hillsides. It varies in color from a deep red to black, is rich in lime, iron, and phosphates, and is often somewhat stiff and clayey.

The air is exceptionally free from dust on the northern side, as might be expected from such a rain-washed atmosphere, and the sky is very blue; but on the dryer side there is naturally more dust, and in Kingston and on the Liguanean Plain there are frequent dust storms, only comparable to those of Boston in the height of the season. What effect the vast amount of decaying vegetation might have on the air, were there little or no atmospheric circulation, it is difficult to estimate; but the constant trades during eight or ten hours of the day, and the "doctor," as the reverse "land breeze" of evening is called, provide for constant and full oxidation of the organic wastes. As to the malarious exhalations of the swamps and low marshy lands, it is difficult to speak authoritatively, but the experience of the people leads them to avoid the evening dews and damps, and to aim at a residence as far above the level as circumstances or convenience will allow. Many parts of the island are comparatively free from malaria, notably the Manchester and Santa Cruz Mountains, before mentioned, and not every one who lives where the disease is prevalent is affected, but most people suffer to a certain extent who remain sufficiently long It does seem, however, that those whose vital forces are strongest, who are well nourished and clothed, and who avoid chill and dampness, are most immune to this, as to any other disease.

Water.

In a chemical analysis of water there are three principal factors: first, nitrogen in the four forms of free ammonia, albuminoid ammonia (indicating the organic nitrogen), nitrites, and nitrates; second, lime and magnesia; and third, chlorine.

The nitrogen may come in the form of albuminoid ammonia from the living microscopic or visible organisms existing in the water, or from decaying vegetable matter, or in the form of free ammonia and

nitrites from decaying animal matter or from animal or household wastes, and may vary from organic ammonia, suspicious ammonia, and nitrite to the inorganic and innocuous nitrate. These variations depend simply on the degree of oxidation of the organic matter, the ammonia being the first product of decay. Further, nitrogen is essential to plant life, and this cycle of change may be interrupted at any point and the nitrogen withdrawn from circulation. Nitrogen may or may not, therefore, be an exact indication of the extent of contamination.

The amount of lime and magnesia determines the degree of hardness, but does not necessarily affect the quality of the water except when excessive, that is, in a limestone region; in a granitic country presence of lime and magnesia salts might indicate contamination from cesspools and the like.

In chlorine we have a factor of greatest importance in sanitary interpretation, when intelligently used. Common salt, of which chlorine is the active principle, is a necessity for man and beast. But little of it is retained in the system, however, and the chlorine, leaving the body with other wastes, is not absorbed by vegetation as are the nitrates, but being very soluble in all ordinary compounds, when once in the water is not lost, but remains there as a tell-tale of a most useful character. This demand for salt is so universal and the amount consumed is so constant, that the quantity of chlorine found in a sample of water becomes an excellent index of the degree of contamination, *provided* we know the amount of salt rightfully belonging to that locality, coming from that great repository of chlorine, the ocean. The importance of this knowledge of the normal amount of chlorine for a locality may be easily illustrated. The normal amount for low, sandy, ocean-washed Nantucket is 2.16 whole parts per 100,000 parts of water, while North Adams in the western part of the State, 140 miles from the coast, has a normal of .06 parts per 100,000. Now the last published analyses for the water of the Hoosac River at North Adams give about .40 parts per 100,000. The sewage-polluted Hoosac River has, then, but one-fifth as much chlorine as the well-filtered and perfectly safe water of Nantucket, and any one unacquainted with the facts would, on the basis of the chlorine, give an absolutely erroneous decision. The State Map of Normal Chlorine, however, shows us that the chlorine of Hoosac River is seven times the normal for that locality, and the question is at once decisively

settled. The great importance of the normal chlorine chart to the sanitarian will be evident from the foregoing. The information upon which was based the first normal chlorine map of Massachusetts included thousands of analyses, made during two years and cost thousands of dollars. This large expense was necessitated by the widely scattered population in Massachusetts and consequent variation of the contamination of the waters. A very limited number of analyses for a single locality might have answered, had the region been uninhabited and uncontaminated.

In Jamaica the circumstances which, as before described, limited the towns to a narrow line of coast, leaving the interior but sparsely inhabited, made it possible to obtain what may be considered a fairly accurate chart, at least for the northern side of the island, with but seventy-seven samples of water, mostly taken within a few miles of the coast. The water taken from rivers at a distance of one mile from the coast was usually as pure as if taken many miles inland. Even had it been otherwise we should have attacked the problem, as it was probably the first attempt at such an investigation of a large island, and there was hope that with these unusually favorable surroundings we might be able to obtain some light as to the principles underlying certain features of the normal chlorine map of Massachusetts.

Equipment.

Through the kindness of the Boston Fruit Company we were furnished with two carriages and mules to transport apparatus and luggage. A dozen four-liter demijohns, and six dozen quart bottles (in crated cases) carefully sterilized, and packed to avoid breakage, were carried, as well as a bacteriological outfit.

Our plan was to circle the island on the main road, to bottle a sample of the purest river or brook water obtainable at intervals of five to ten miles, and to give a full description of the appearance and surroundings of each sample, with our impression as to its purity; and besides to obtain, where possible, the cistern rain waters, which would give the chlorine in the rain and atmosphere only, except as affected by the cement linings of ground cisterns. The case when filled with samples was sent to Boston. So successfully was this collection done that but one sample had to be completely rejected as being mixed with sea water. That particular sample was accompanied

by the notation that it was "possibly brackish," and was bottled because it was the only one obtainable in several miles. Some few showed evidence of contamination, but in each case, fortunately, we had an undoubtedly pure brook or river water in the near vicinity to check with. The analyses were made entirely at the Institute of Technology, and the results check admirably with our knowledge of the surroundings. It is another evidence of the truth of the saying that "the sanitary engineer *must* collect his own samples." Had these samples been taken by an inexperienced person, or had they been submitted with no data as to localities and surroundings, the results would in some cases have been entirely uninterpretable.

Analyses.

The exhaustiveness of the analyses depends, primarily, on the amount of water available. The quart bottle samples were tested for turbidity, sediment, color, hardness, chlorine, nitrogen as nitrate, and in a few cases for the ammonias. The demijohn samples were given a further examination for nitrogen as ammonia and nitrite and for iron, while some five samples were further analyzed for silica, sulphuric acid, aluminum, calcium, and magnesium. Then on an outline tracing of the map of Jamaica the results of the analyses for chlorine were written in, on the spot from which the sample was obtained, and iso-chlors, or lines of equal chlorine, drawn with due allowance for evident contamination from adjacent villages and from salt springs, of which there are several. The chlorine of cistern waters cannot be used directly as a basis for normal chlorine, being always too low. Cistern water, generally speaking, contains only the chlorine from the rain and from its own particular watershed, generally a roof, and is but little concentrated by evaporation. Pure river water chlorine under the usual climatic conditions generally represents that which is normal to the locality after the usual evaporation has been effected.

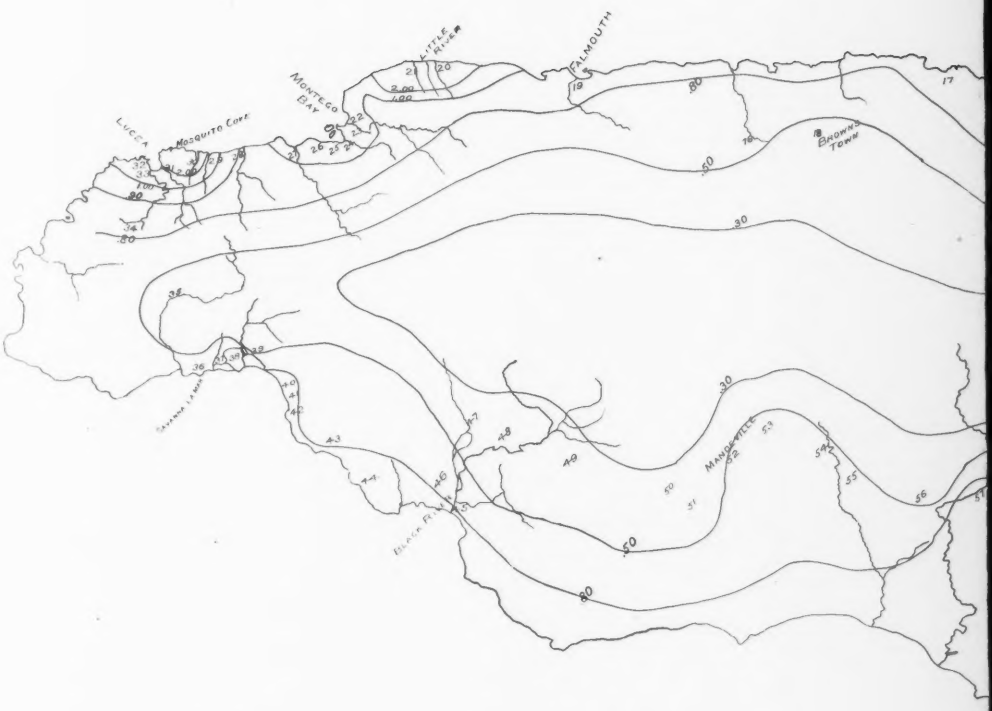
While strict accuracy cannot be claimed (for this would require repeated examinations of a wider range of territory, extending over a considerable period of time and during the different seasons of the year), we are satisfied as to the general reliability of the results of our studies.

I. TABLE OF ANALYSES.

Number.	Appearance.			Hardness.	Ammonia.		Chlorine.	Nitrogen as nitrates.	Nitrogen as nitriles.
	Turbidity.	Sediment.	Color.		Free.	Albuminoid.			
1	None.	Slight sandy.	0.00	21.8	.0000	.0000	1.53	.0200	.0000
2	None.	Slight sandy.	0.00	14.4	.0000	.0000	.79	.0050	.0001
3	Slight green.	Considerable green.	0.05	50.0	.0012	.0044	7.48	.1600	.0006
4	Very slight.	Considerable rusty.	0.12	24.5	.0052	.0106	1.90	.0050	.0000
5	None.	Slight rusty.	0.05	6.4	.0000	.0000	.72	.0030	.0001
6	Slight.	Considerable earthy and rusty.	0.03	18.2	.0000	.0016	.70	.0380	.0001
7	Very slight.	Slight.	0.03	8.3	....	....	.51	.0050	....
8	Very slight.	Slight.	0.03	10.1	....	....	.77	.0030	....
9	Very slight.	Slight.	0.05	10.1	....	....	.80	.0030	....
10	Very slight.	Slight.	0.12	16.9	....	....	1.16	.0050	....
11	Very slight.	Slight.	0.05	13.3	....	....	.87	.0030	....
12	Very slight.	Slight rusty.	0.03	33.4	....	....	2.39	.0050	....
13	None.	Slight.	0.03	19.9	.0000	.0020	1.27	.0070	....
14	None.	Slight.	0.04	12.3	....	....	1.31	.0070	....
15	None.	Slight.	0.03	16.4	....	....	.89	.0600	....
16	None.	Slight sandy.	0.01	12.4	....	....	.84	.0450	....
17	None.	Slight sandy.	0.01	13.3	....	....	.79	.0620	....
18	None.	Slight earthy, cyclops.	1.30	2.2	....	....	.46	.0120	....
19	Very slight.	Considerable earthy and rusty.	0.00	18.3	.0000	.0000	.71	.0700	.0000
20	Slight clayey.	Considerable clayey and sandy.	0.00	13.8	....	....	2.87	.0400	....
21	Slight clayey.	Considerable clayey.	0.40	12.3	....	....	3.30	.0200	....
22	None.	Very slight.	0.00	18.0	.0008	.0000	.95	.0400	....
23	Very slight.	Slight organisms.	0.00	18.6	....	....	1.65	.0400	....
24	Very slight.	Slight rusty.	0.10	19.9	....	....	1.79	.0280	....
25	Very slight.	Slight sandy.	0.05	16.7	....	....	1.01	.0220	....
26	None.	Very slight.	0.00	23.0	....	....	.96	.0550	....
27	None.	Very slight.	0.08	17.2	....	....	1.12	.0220	....
28	Very slight.	Slight.	0.04	16.9	....	....	.84	.0150	....
29	None.	Slight.	0.01	12.1	....	....	.74	.0200	....
30	Very slight.	Slight.	0.02	14.2	....	....	3.05	.0070	....
31	Very slight.	Slight rusty.	0.03	74.9	....	....	135.0	.0050	....
32	None.	Very slight.	0.01	18.3	.0000	.0000	1.56	.0500	....
33	None.	Slight gelatinous.	0.00	19.6	....	....	2.70	.0250	....
34	None.	Slight rusty.	0.20	16.9	....	....	2.09	.0070	....

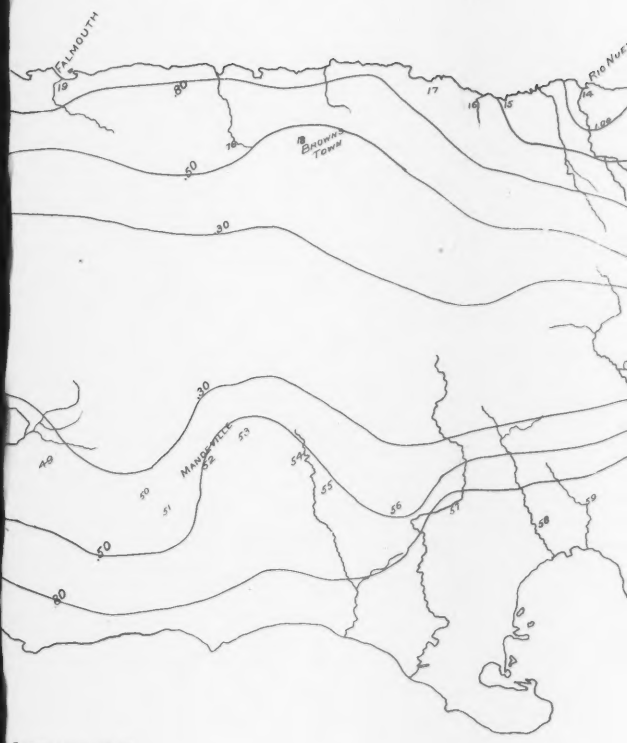
I. TABLE OF ANALYSES. — *Continued.*

Number.	Appearance.			Hardness.	Ammonia.		Chlorine.	Nitrogen as nitrates.	Nitrogen as nitrites.
	Turbidity.	Sediment.	Color.		Free.	Albuminoid.			
35	None.	Very slight.	0.00	16.7	....	....	.45	.0170	....
36	None.	Very slight.	0.00	22.7	....	....	.52	.0250	....
37	None.	Slight.	0.18	22.0	....	....	.67	.0050	....
38	None.	Slight.	0.05	19.6	....	....	.51	.0050	....
39	None.	Very slight.	0.00	21.2	.0016	.0012	.47	.0220	....
40	None.	Slight rusty.	0.07	22.9	....	....	.90	.0400	....
41	None.	Very slight.	0.01	18.2	....	....	.80	.0400	....
42	None.	Slight.	0.01	14.8	....	....	.50	.0400	....
43	None.	Slight.	0.01	14.8	....	....	.67	.0400	....
44	None.	Slight.	0.05	20.7	....	....	6.00	0.170	....
45	None.	Slight rusty.	0.20	17.9	....	....	.37	.0500	....
46	None.	Very slight.	0.00	22.0	....	....	.75	.0650	....
47	None.	Very slight.	0.00	12.7	....	....	.37	.0400	....
48	None.	Slight.	0.03	16.3	....	....	.51	.0400	....
49	None.	Very slight rusty.	0.33	5.4	.0012	.0040	.14	.0100	....
50	None.	Slight rusty.	0.42	9.1	.0000	.0156	.32	.0200	....
51	Distinct milky.	Slight rusty.	0.60	5.0	.0000	.0042	.17	.0050	....
52	None.	Very slight gelatinous.	0.50	4.9	....	....	.19	.0350	....
53	None.	Considerable rusty.	0.05	8.0	.0000	.0128	.67	.1000	....
54	None.	Slight rusty.	0.07	18.5	....	....	.57	.0070	....
55	None.	Very slight.	0.05	16.1	....	....	.65	.0300	....
56	None.	Very slight rusty.	0.80	6.3	....	....	.40	.0250	....
57	None.	Slight.	0.00	11.9	.0000	.0000	.87	.0050	....
58	None.	Very slight.	0.00	19.9	....	....	1.80	.0050	....
59	Distinct milky.	Slight clayey.	0.20	20.2	....	....	.89	.0580	....
60	None.	Slight.	0.05	15.0	....	....	.89	.0320	....
60*a*	None.	Slight.	0.00	14.9	.0000	.0012	.88	.0250	.0001
61	None.	Slight.	0.02	10.00	.0000	.0000	.32	.0050	.0000
62	None.	None.	0.02	12.90	.0000	.0000	.37	.0030	.0000
63	None.	Very slight.	0.07	13.6	....	....	.72	.0030	....
64	None.	Very slight.	0.02	59.5	....	....	2.50	.0030	....
65	None.	Very slight.	0.00	11.9	....	....	.60	.0050	....
66	None.	Slight.	0.05	22.2	.0034	.0016	1.12	.0070	....
67	None.	Very slight.	0.02	30.0	....	....	2.90	.0420	....



THE NORMAL CHLORINE CHART OF JAMAICA, JANUARY, 1898.

The places where the samples described in the tables were taken are indicated by the corresponding numbers on the chart. The decimals upon the iso-chlors show the parts of chlorine per 100,000 parts of water.



JANUARY, 1898.

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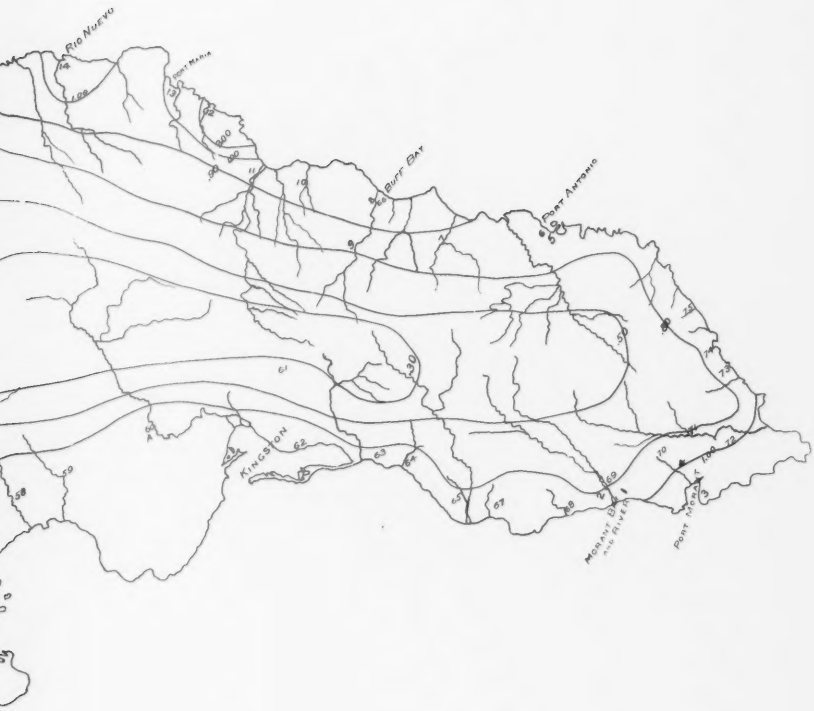
RIO NUEVO
PORT MARIA
BUFF BAY
PORT ANTONIO
KINGSTON
MORANT BAY
PORT MORANT

I. TABLE OF ANALYSES. — *Concluded.*

Number.	Appearance.			Hardness.	Ammonia.		Chlorine.	Nitrogen as nitrates.	Nitrogen as nitrites.
	Turbidity.	Sediment.	Color.		Free.	Albuminoid.			
68	None.	Slight.	0.03	21.7	....	....	1.47	.0500	....
69	Very slight.	Slight earthy and rusty.	0.02	19.1	.0000	.0056	1.35	.0320	.0005
70	None.	Very slight.	0.02	19.6	....	....	1.16	.0520	....
71	None.	Slight.	0.30	12.4	....	....	.67	.0050	....
72	None.	Very slight.	0.02	26.6	.0000	.0004	1.22	.0050	.0000
73	None.	Slight.	0.02	15.0	....	....	.97	.0100	....
74	None.	Slight.	0.00	15.9	....	....	.61	.0070	....
75	None.	Very slight.	0.02	21.7	....	....	.86	.0220	....
76	Very slight.	Considerable earthy and rusty.	0.00	18.3	.0000	.0000	.71	.0700	.0000

II. TABLE OF REMARKS.

Number of sample.	Source.
1.	From town supply; Morant Bay; reservoir well located.
2.	Irrigating canal from Johnson River; one mile inland.
3.	Well 15 feet diameter, 22 feet deep; surface water; slight scum on top; 100 feet from sea.
4.	Phillips field; well located reservoir; heavy growth on shore; three miles inland.
5.	Town supply; Port Antonio; reservoir small; peasant houses three hundred yards above.
6.	Wharf supply; reservoir larger; no houses nearer than five hundred yards.
7.	Swift river; deep and rapid; rises ten miles away in mountains; one and a half miles inland.
8.	Buff Bay River; deep water; river rises fifteen miles back; one mile inland.
9.	Buff Bay River; three miles above (8).
10.	Dry River; low water; rises twenty miles distant; few villages on banks; one mile inland.
11.	Agualta River; one mile inland; under bridge women washing clothing; rises fifteen miles inland.
12.	Crawl Pond Spring; three miles inland; taken above fording.
13.	Town supply; Port Maria; reservoir fairly well protected.
14.	Sambo River; near sea; few settlements on river.
15.	Bungalo River; near shore.
16.	Roaring River; one-half mile inland.
17.	Landovery River; near shore; a mountain stream.
18.	Brownstown; cistern water from roof.
19.	Dornack River Head; a sink hole; water comes underground several miles.
20.	Roseall River (Little River); taken near coast; only one mile in length.
21.	White Gut; small brook near coast.

Number of sample.	Source.
22.	Town supply, Montego Bay; from Barnet River.
23.	Small stream; one mile from shore on Arwin estate.
24.	Barnet River; taken under bridge; villages near; rises in the mountains.
25.	Jerry Duncan River; rises in interior; taken one mile inland.
26.	Redding River; a mountainous stream near coast.
27.	Great River; near shore; still water; perhaps some chlorine.
28.	Flint River; a large stream; houses near on banks; comes great distance.
29.	Brook on Tryall estate; used for water power; probably unpolluted.
30.	Mr. Davis's brook; a small stream one mile from coast.
31.	Kew Bridge; "backwater" near coast; possibly brackish.
32.	Town supply, Lucea; from Prospect; two miles inland.
33.	Great well; unfavorable surroundings.
34.	Morgan's Brook; small; probably no contamination.
35.	Picket's River; a deep stream; rises up country.
36.	Town supply; Savanna La Mar; from spring five miles distant.
37.	Smithfield Brook; small shallow stream one and a half miles inland.
38.	Lochiel Spring; small brook.
39.	Deans Valley River; fair size; but few inhabitants.
40.	Cave Brook; small; comes from back country; near coast.
41.	Clear running brook.
42.	Bluefield River; rapid brook from hills.
43.	Akindown River; comes from foot hills through estate; cattle near; washing place.
44.	Scott's Cove Brook; small flowing stream; clear; comes from hills; no houses near; cattle abundant.
45.	Black River; tap; reservoir six miles from coast; good conditions.
46.	Spring Head; a small spring brook.
47.	Shaw's River; deep, quietly flowing; villages on banks.
48.	Black River at Lacovia; deep river; many villages on banks.
49.	Santa Cruz; cistern water from roof of constabulary station; cedar shingle roof.
50.	Elginton; water from cemented limestone cistern nine feet deep, ten feet diameter.
51.	Spur Tree Pen; cistern forty by one hundred feet; twenty feet deep; water flows down hillside; cattle on hills.
52.	Mandeville; water from concreted cistern twenty feet diameter, fourteen feet deep; Mrs. Halliday's lodgings.
53.	Williamsfield; cistern water used on railway; contaminated by street flowage.
54.	Belvidere; small brook across road; comes from hills; probably uncontaminated.
55.	Clarendon Park; small running brook.
56.	Four Paths; cistern water at constabulary station; rain from roof.
57.	May Pen; town supply; no particular care of reservoir.
58.	Old Harbour; town supply from mountain springs.
59.	Dry Harbour; water from Irrigation Canal.
60.	Spanishtown Irrigation Canal; Rio Cobre River.
60*a*.	Town supply at Spanishtown; water from Rio Cobre River; fairly good conditions.
61.	Constant Springs Hotel; water from tunnel to Wag Water River; good conditions.
62.	Town supply of Kingston at Myrtle Bank, from Wag Water River.
63.	Cane River near mountains; no settlement visible.
64.	Chalk River; small milky white stream from mountains; no apparent contamination; limestone.

Number of sample.	Source.
65.	Albion River from mountains; very little contamination.
66.	Buff Bay; well in yard; dug in limestone; low ground; contamination of surface water.
67.	Mundicott River; contaminated by washing, etc.; fairly large river.
68.	White Horses; brook comes over cliffside; uncontaminated.
69.	Morant estate; small reservoir; cattle about.
70.	Small brook from hills; probably very good.
71.	Devil's River; from the mountains; fair.
72.	Swift's Spring, Golden Grove; six inches deep, four feet diameter; exposed to surface contamination.
73.	Small river from mountains; somewhat muddy.
74.	Muirton River; large; from mountains; very fair.
75.	Mulatto River; small running stream from mountains; good.
76.	Falmouth; town supply from river two miles inland.

Interpretation.

The iso-chlors drawn on the map are those for two, one, nine-tenths, eight-tenths, five-tenths, and three-tenths parts per hundred thousand. The first thing noticeable is that the iso-chlors for two whole parts per hundred thousand begin and end in the seacoast and inclose rather small areas, that those for one and nine-tenths parts are similar but of greater extent, while the remaining iso-chlor areas cover the central portions of the island, more or less evenly spaced between the northern and southern coasts.

There are three distinct areas covered by the iso-chlors for two parts per hundred thousand, the districts about Rio Nuevo, Little River, and Mosquito Cove. Now, as a matter of fact, each of these three districts consists of a more or less narrow plain backed by a wall of mountains extending to the sea on either side, which effectually shuts in the rain and salt spray from the Carribean Sea blown against that part of the coast. Consequently we have, condensed in a small area, an amount of salt which but for the mountain barrier would be spread over a territory perhaps several miles in depth and with a lower normal chlorine.

It will be noticed that the Port Morant and Plantain Garden River district has an isolated iso-chlor for one part per hundred thousand; this results from the diversion of the northeast trade by the John Crow Mountains previously mentioned, and is a necessary accompaniment to the generous rains which have made this limited district so important in the sugar cultivation of the past and the banana plantations of the present.

We have already mentioned the curious and important fact of the generally equal spacing of the iso-chlors for eight-tenths parts and less, with respect to the northern and southern coasts. This was, we confess, entirely unexpected by us. We had looked to find a high chlorine along the northern coast, somewhat greater than on Cape Cod, because of the greater degree of concentration of the ocean in that latitude. Our disappointment in this regard was probably due to the general moderation of the winds in the Carribean Sea, for investigations in Massachusetts indicate that the amount of chlorine carried depends on the force of the winds bearing inland the salt spray from the coasts. We had also expected to find a very low chlorine on the southern side generally, reasoning that the high mountain wall which shut out so much of the rain would also prevent the entrance of chlorine. Why, then, this discrepancy between theory and fact? It is due to the neglect of a very important factor obtaining in tropical countries having excessive precipitation and evaporation. This factor we may term "the dilution and concentration of chlorine." The rainfall for the northern and eastern districts is very great, ranging from 100 to nearly 200 inches in a year (the showers coming at frequent intervals, but being especially concentrated in the May and October seasons), and this gives a large amount of water to a given amount of chlorine. It must be remembered that the chlorine should be a very constant factor, being directly dependent on the proverbially constant trade winds. This large if somewhat variable amount of water, then, dilutes the chlorine to an apparently small quantity, although even here the excessive evaporation serves to concentrate the chlorine in river or surface water to an amount considerably in excess of that in cistern (or rain) waters. On the dry side of the mountains we have the reverse conditions, the amount of rainfall is so moderate, about one-quarter to one-third that of the weather side, and it is further so reduced by evaporation that there is a considerable concentration of the chlorine, giving the results referred to.

This theory tallies favorably with the results obtained from certain cistern waters in both regions, north and south. Rain water contains only the chlorine in the atmosphere, and when it is collected in uncontaminated and non-evaporating cisterns, represents this atmospheric chlorine very exactly. The cistern water at Brownstown in the north contains .46 parts of chlorine, about two-thirds that of the near-by uncontaminated Dornack River. The cistern water at Mandeville just

over the mountains to the south shows .18 parts of chlorine, while the nearest uncontaminated brooks show .57 and .65 parts respectively. In short, while the cistern water on the weather side showed nearly three times as much chlorine as that from behind the mountains, the surface waters were almost alike.

The case of Port Antonio is a curious one. It has, perhaps, the greatest rainfall of any place in the island, is surrounded by mountains, and is directly in the path of the trade winds, yet its chlorine is very moderate, coming in the third group. It is easily understood, however, when the facts are considered. Two supplies were examined: one, the general town supply; the other, that belonging to the fruit company and supplying the ice factory and the ships. Both waters come from streams in the mountains back of the town, at an elevation of some 1,500 feet. Both reservoirs have an excessive supply of water, fully as much water running to waste as is consumed. One reservoir is probably above the level where salt spray might reach it; the other is possibly within its reach during heavy blows. Chlorine simply does not reach these waters to any extent except during unusual weather. A slight preponderance of chlorine in the water from the town supply over the other is due to the people living on its watershed. This reminds us of Mr. Stearns's statement, that an increase of 28 persons per square mile in any section would raise the chlorine for that section one-tenth part. It is an interesting fact that on these two adjoining watersheds, each containing about one square mile, there are probably two dozen more persons living on one than on the other, while the actual difference in chlorine is .07, nearly a tenth.

Our Normal Chlorine Map for Jamaica has an important point of similarity with that for Massachusetts, in the corresponding distances of the iso-chlors from the coast. Our lowest line, .30, and probably the one most free from disturbing local influences, varies between ten and twenty miles from the coast; that for Massachusetts is about twenty miles inland, with the advantage of a smoother topography. The iso-chlor for .80 is at an average distance of about five miles inland, closely corresponding with the Massachusetts line. This is valuable corroboration of the belief that the amount of chlorine varies inversely with the distance from the coast.

In view of these facts, we think the Normal Chlorine Map of Jamaica may justly be regarded as an interesting contribution to the knowledge on this important subject. Not only do its correspondences with the map for Massachusetts confirm the theories of the

distribution of chlorine, but in an even more marked degree are its differences a witness to the correctness of those conclusions.

The analyses for hardness, nitrates, and color follow in a general way those for chlorine, with, however, higher figures for the leeward side. It is reasonable that there should be more lime in rivers with a slight current and little water, and that such rivers should be more favorable to the growth of algæ, which tends to increase the nitrogen and color. The greatest degree of hardness obtained was, naturally, at "Chalky River," a river milky white with lime. The temporary hardness equalled or exceeded the permanent for most of the waters examined. The highest color was found in cistern waters, most of the river waters having almost none.

A word as to the cisterns. Those in rainy districts were mostly of wood attached to the roof gutters by spouts, but those in the vicinity of Mandeville, where great capacity is required, were dug and cemented cisterns, 20 to 50 feet in diameter and 20 feet deep, sometimes connected with roofs, but more frequently so built that the hillside could be used as a watershed. One such cistern was rectangular, 40 by 150 feet and 20 feet deep, situated at the foot of a considerable slope, and having the ground covered with cement for over 100 feet around. We have examined a few wells also in the course of the investigation, but the less said of them the better.

This investigation has included, with two or three exceptions, all the public supplies of the island, all the rivers of any importance, and a large proportion of the smaller rivers and brooks. Had it been possible, we would have obtained several samples from each river, at increasing distances from the coast. This task we must leave for some future occasion. Seventy-seven samples in all were collected, and four hundred miles traveled over in carriages.

Of the public supplies examined, none could be absolutely condemned on the evidence of but one analysis and without a careful inspection of the reservoirs and watersheds. It should be stated, however, that we found several waters, mostly on the south or dry side, suspiciously high in chlorine and in nitrites. Some few of the brooks and rivers, as also the wells examined, showed evidence of contamination, but most of the waters were really very good. A serious attempt was made to check the chemical analyses by bacteriological analyses made on the spot. Experience quickly showed the impracticability of this on account of the very limited period of time available, and the lack of ice.

AN IMPROVED FILTER FOR MICROSCOPICAL WATER ANALYSIS.

By DANIEL D. JACKSON, S. B.

The greatest percentage of error in the microscopical analysis of water by the Sedgwick-Rafter method is found in the examination of those waters which contain a large number of delicate Protozoa. There is hardly a surface water which does not contain some of these organisms, and the plankton of some waters is often very largely made up of them.

A careful study of the method of analysis will point out the reason for this great loss in Protozoa. The measured quantity of water passes entirely through the sand, and very little moisture is left. This is quite sufficient in itself to break up a large percentage of the more delicate forms in water, but the organisms are then washed down into the tube by water of a different specific gravity (often distilled water), and the result is that some of the microscopic growths which survive the partial drying process on the filter are collapsed by the change of media. Occasionally when a water is swarming with some delicate form of Protozoa, only a few, or perhaps none at all, are discovered after filtration.

This very serious difficulty is now obviated by an attachment to the filter funnel which holds back a definite quantity of the original water in the funnel. No change in the method of analysis is necessary, and the original filter funnel, as devised by the author and described in a previous article,[1] is used, but to the bottom of this funnel is fitted an attachment by means of a ground glass connection.

The attachment consists of a prolongation of the filter tube, and is closed at the bottom by means of a solid rubber stopper. A smaller tube is connected with the main tube by a T joint, and rises just to the level of the six-cubic-centimeter mark on the funnel. This tube is

[1] *Technology Quarterly*, Vol. IX, No. 4, Dec., 1896.

in consequence of such a height that, when the solid rubber stopper is in place, all the water may filter through the sand except five cubic centimeters.

The ground glass on the bottom of the funnel has a well-marked upper border, and the perforated rubber stopper (with a wet pellet of No. 20 silk bolting cloth over the upper opening) is inserted into the bottom of the funnel up to this mark. Then exactly two cubic centimeters of sand is measured out and poured into the top of the funnel. If the sand is 60-120 mesh Berkshire[1] (quartz), it will hold one cubic centimeter of water, and therefore, when covered with water will displace exactly one cubic centimeter. Hence, from the top of the rubber stopper to the mark corresponding to the top of the small upright tube, the capacity of the tube should be exactly six cubic centimeters.

The perforated rubber stopper must be of such a shape that the attachment may be put on and taken off quickly without interference. The bottom of the attachment is open so that the solid rubber cork which fits into it may be left out, if desired, until the latter part of the operation, thus gaining in the rapidity of filtration. Some of the filtrate may be used to wash down the sides of the funnel after the water has fallen sufficiently in height.

Without suction the process of direct filtration requires half an hour. Filtration without suction, but with the solid rubber stopper in place, requires over an hour, but the latter part of the process will take much less time if slight suction be applied by means of the mouth and an intercepting bottle.

The dimensions of the filter funnel as described in a previous article are as follows: "The inside diameter of the top of the funnel is 2 inches, the distance from the top to the beginning of the slope is 9 inches, and the length of the slope is 3 inches. The tube of small bore at the bottom is $2\frac{1}{2}$ inches long and $\frac{1}{2}$ an inch in inside diameter."[2]

The illustration accompanying this article shows a battery of filter funnels, and, in front, a funnel with the new attachment at the bottom. The main part of the attachment is $1\frac{1}{2}$ inches long, $\frac{1}{2}$ an inch

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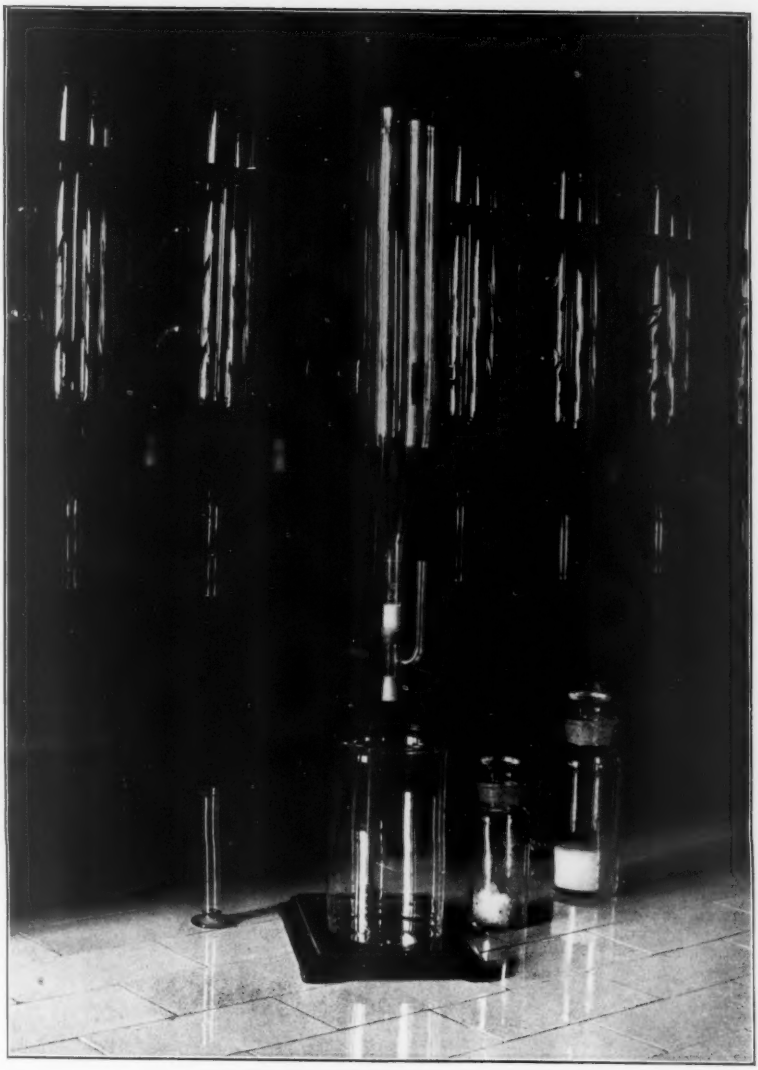
[1] Berkshire Glass Sand Co., Chester, Massachusetts.

[2] The most satisfactory funnels, with or without the attachment, have been obtained from Richards & Co., 30 East 18th Street, New York City.



FILTER FUNNELS FOR SEDGWICK–RAFTER METHOD.

in inside diameter, and has a ground glass connection with the filter funnel. The small upright tube is $\frac{1}{4}$ of an inch in bore and is joined to the main tube $\frac{3}{4}$ of an inch below the top.

When the funnel is ready and the attachment is in place, 250 cubic centimeters of the water to be examined is poured into the top of the funnel. Filtration is rapid at first, but toward the end it becomes very slow, and then slight suction is applied to the small upright tube and the water drawn down till the bottom of the meniscus just reaches the six-cubic-centimeter mark. Just before the analyst is ready to examine the concentrated water with the microscope, the attachment is quickly removed, and a wide test tube is placed beneath the perforated rubber stopper. This stopper is then carefully withdrawn from the bottom of the funnel, and all of the sand and water is allowed to run into the test tube. The test tube is then shaken by a rotary motion in order to distribute the organisms equally. Then the sand is allowed to drop to the bottom of the tube suddenly, and the water, without the sand, is quickly decanted into another smaller test tube from which, after careful mixing, one cubic centimeter is taken for examination, as described in previous articles upon the subject.

Very careful experiments have been performed upon the use of the centrifuge in the microscopical examination of water, and the results obtained in this manner first pointed out the large error in the estimation of Protozoa by the Sedgwick-Rafter method. The centrifuge may be used with a considerable degree of success in the volumetric determination of plankton in water for the fish industry, but its use in the accurate qualitative and quantitative microscopical examination of drinking water is open to serious objection. The chief errors by this method come from the matting together of the material to be examined, thus preventing even distribution on the slide, and from the fact that the Cyanophyceæ and also other microscopic organisms of low specific gravity are precipitated only in small percentages.

Exhaustive experiments have been carried on also to find a filtering material which would replace the quartz sand. Occasionally a water contains a considerable number of very minute forms, hardly larger than bacteria, and quite a large percentage of these will pass through the sand filter. In order that the microscopic organisms may be properly collected for examination a very small filtering area must be used. It has been found that pellets of such filtering material as is used in the Pasteur and Berkefeld filters will hold these forms back,

but will filter so slowly, even with strong suction, that their use is entirely impractical. When these very minute organisms are found in the filtrate, they may be concentrated by means of the small Berkefeld filter using suction, and the figures thus obtained from the filtrate may be added to the analysis by the Sedgwick-Rafter method. If these minute forms are in sufficient numbers, they may with at least equal accuracy be examined directly from the original sample of water.

The following table gives a partial analysis of a representative surface drinking water, in which the results of filtration with and without the attachment are compared. Only those forms are given which might be affected by the use of the attachment. It will be seen that the figures corresponding to the more hardy forms of Protozoa are not increased by its use.

	Without attachment. No. per cc.	With attachment. No. per cc.
CHLOROPHYCEÆ.		
Zoospores	8	56
PROTOZOA.		
Mallomonas	4	4
Peridinium	2	2
Dinobryon	16	16
Bursaria	0	2
Halteria	0	4
Cryptomonas	8	40
ROTIFERA.		
Asplanchna	1	2

A comparison of results with and without the attachment to the filter funnel shows practically no change in the number of Diatomaceæ, Chlorophyceæ (except in zoospores), Cyanophyceæ, Fungi or Crustacea, but in the Rotifera, and especially in the case of the delicate forms of Protozoa, a decided increase in number is noted. In other words, the hardy microscopic organisms, or forms not easily destroyed, have given little error in the analysis without the attachment, but the more delicate forms, most of which are included under

the Protozoa, require that the attachment should be used in order that an accurate analysis may be obtained.

It will be seen also that the error due to an unknown quantity of water left in the sand after filtration is entirely eliminated by the use of the attachment.

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THE ACETYLENE STANDARD OF LIGHT.

By H. E. CLIFFORD and J. S. SMYSER.

In an investigation of some of the photometric properties of the acetylene gas flame recently carried on at the Institute, results were obtained which will be briefly stated, together with an explanation of the diagram of the apparatus used. The diagram shows merely the arrangement of the apparatus, and is not a scale drawing.

The generator, *d*, Figure 1, is made of heavy galvanized iron. Calcium carbide is introduced in the form of large lumps, and the top is then closed by a cast-iron plate *a*, faced smooth, and having a rubber gasket between it and the top of the generator. The plate is held in place by means of a wrought-iron yoke *b*, through the top of which is a screw bolt *c*, which forces the gasket tight against the plate and the top of the generator, thus preventing any leak of gas at this point.

The generator stands in a galvanized iron cylindrical reservoir *e*, and is surrounded by water up to within three or four inches of the top, means being provided for keeping a circulation of cool water through this outer reservoir, so that the heat which is developed within the generator can be carried off easily. A small glass reservoir *f* is attached to the top of a pipe *g*, leading to the generator, provided with a stop-cock *h* and a tube *i*, which connects the space above the surface of the water within it with that below, thus insuring a flow whenever it is needed. A piece of rubber tubing *j* forms part of this by-pass, so that it can be closed by a pinch-cock *k* when it is necessary to refill the reservoir.

Another pipe *l*, leading from the generator, branches, one branch *m* leading to a gas holder *o* of about 3 cubic feet capacity, the other *n* to the air outside the building, so that in case the gas is generated too rapidly a part of it can be sent out of doors. A weight *p* is arranged to balance the movable cylinder *q* of the gas holder, and serves to keep it concentric with the other cylindrical parts of the holder, in which it is free to move in a vertical direction.

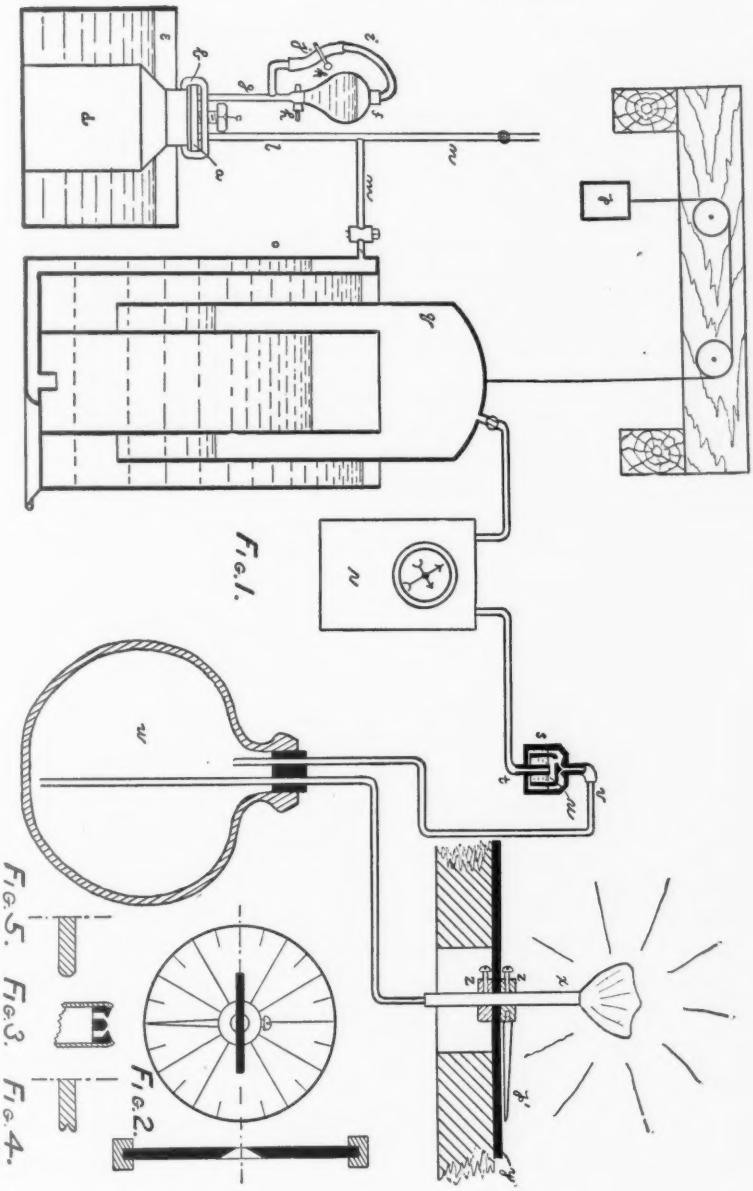


FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

From the gas holder connection is made by rubber tubing and lead pipe to a one-light acetylene gas meter *r*; and from here to a small rheometer or pressure regulator *s*, shown in section. This is merely a small brass reservoir into which the pipe *t* projects, and which is partly filled with oil. Within this space and resting in the oil is the regulator proper *u*, which resembles an inverted gun cap. Near the top there is a small hole through which the gas passes into the outer space. The top is conical, and is directly below the opening leading from the outer space. When the gas is supplied at a certain rate it passes through this cap-shaped piece, and then out through the pipe *v*. If the pressure increases, the cap rises and partly closes the exit pipe.

Any such regulator as this, however, would tend to produce fluctuations in pressure, even though the average pressure were maintained constant. To reduce as much as possible any such fluctuations before the gas is burned, it is passed into the top of a large empty glass carboy *w*, and then conducted through a pipe leading from the bottom of the carboy to a Bray 1-foot acetylene burner *x*. The latter is fastened to the end of a short piece of brass tubing, which is free to turn in the hole bored in the center of the brass plate *y*. It is capable also of vertical adjustment, the two brass collars *z*, *z*, serving to hold it at any given height. The pipe which attaches to its lower end is made of rubber tubing, so that the burner may be turned freely. A pointer *p'* is rigidly attached to the upper collar, and serves to indicate the angular position of the burner by reference to a graduated circle immediately below it, and concentric with the axis about which it revolves. The stop is located very near the burner, the diameter of the aperture used in these tests being 8.566 mm.

A Methven 2-candle standard was used, and a Lummer-Brodhun photometer, great care being taken to screen the disk from all stray light. Twelve tests were made, each consisting of eighteen double settings (direct and reversed), the mean of each double setting being taken as the setting of the photometer. The flame occupied a different angular position in each test, so that the horizontal intensity was studied at intervals of 30° around the entire circle.

The tests were made by two observers, one making the settings, taking the temperature of the air in the room, and reading the gas meter; and the other keeping the time, recording the settings, and changing the angular position of the flame at the end of each test.

The candle power corresponding to each observation was computed, also the mean candle power for each test, and the average deviation of a single observation — the latter being a measure of the precision with which the settings were made. A series of curves was also drawn, showing the relation between candle power and time for each of the eighteen minutes during which the test lasted. Then another curve was drawn showing the relation between the mean candle power, in each position of the flame, and the angle which the plane of the flame made with the plane of the stop.

In studying the curves from 1 to 12 inclusive, it must be remembered that they are plotted on a very large vertical scale, so that the variations can be more easily seen. A table is given in which the more important facts brought out in the tests are collected. It will be observed that the variation in intensity in each of the twelve tests is, on the average, about 0.5 of a candle power.

Particular attention is called to the columns of mean candle powers, angular positions of the flame, and rates of gas consumption. It will be seen at once that the figures in the latter are very uniform,

Number of test.	Maximum candle power.	Minimum candle power.	Difference.	Angle between the flame and plane of the stop.	Mean candle power.	Gas consumed in cubic feet.	Rate of gas consumption in cubic feet per hour.	Temperature of the air in the room. (Centigrade.)	Average deviation of a single observation. a. d.	Percentage change above minimum candle power.
1	7.38	6.9	.48	0°	7.12	0.355	1.18	20°.0	0.076	6.9
2	10.80	10.40	.40	270°	10.63	0.318	1.06	20°.3	.098	3.8
3	8.06	7.32	.74	330°	7.71	0.308	1.03	20°.4	.170	10.0
4	11.20	10.50	.70	300°	10.90	0.283	0.94	20°.7	.200	6.7
5	11.80	11.20	.60	240°	11.40	0.283	0.94	20°.8	.100	5.0
6	7.96	7.58	.38	210°	7.71	0.308	1.03	25°.7	.080	5.0
7	7.10	6.62	.48	180°	6.83	0.307	1.02	25°.7	.110	7.2
8	8.18	7.64	.54	150°	7.74	0.283	0.94	22°.0	.073	7.0
9	11.18	10.76	.42	120°	10.96	0.313	1.04	22°.2	.086	3.9
10	10.74	10.34	.40	90°	10.46	0.342	1.14	24°.5	.0075	3.8
11	12.48	11.84	.64	60°	12.14	0.318	1.06	24°.5	.148	5.4
12	8.48	7.90	.58	30°	8.24	0.308	1.03	25°.7	.146	7.3

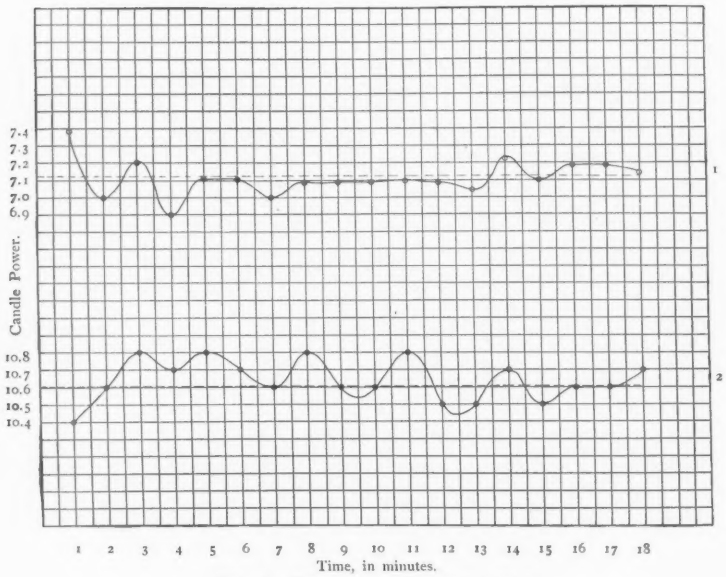
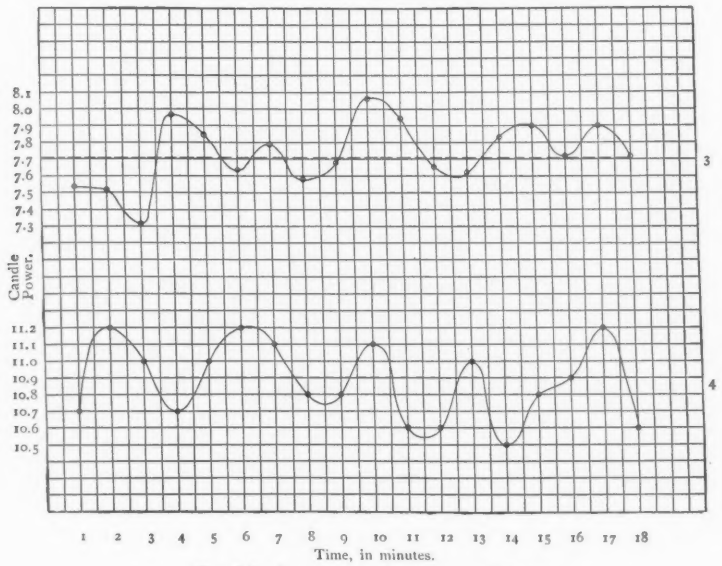


FIG. 6. CURVES FOR TESTS 1 AND 2.



Dotted line in each curve shows mean candle power.

FIG. 7. CURVES FOR TESTS 3 AND 4.

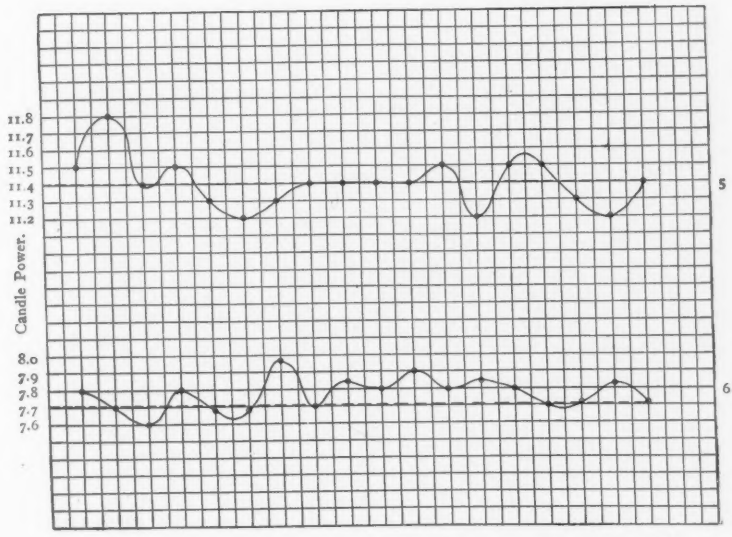
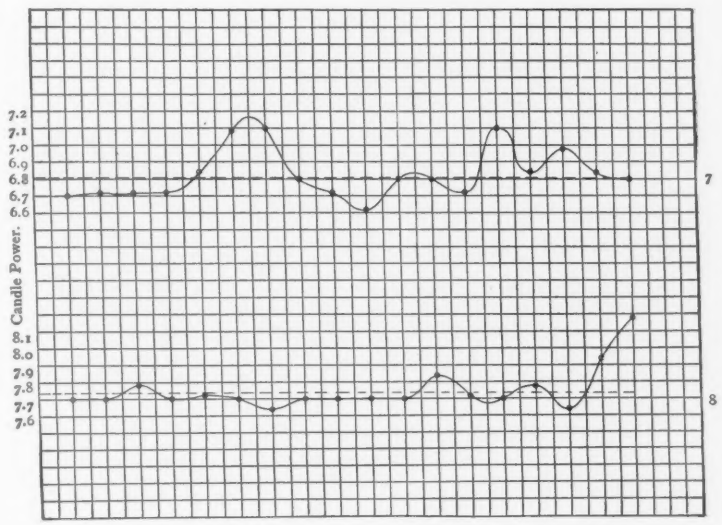


FIG. 8. CURVES FOR TESTS 5 AND 6.



Dotted line shows mean candle power.

FIG. 9. CURVES FOR TESTS 7 AND 8.

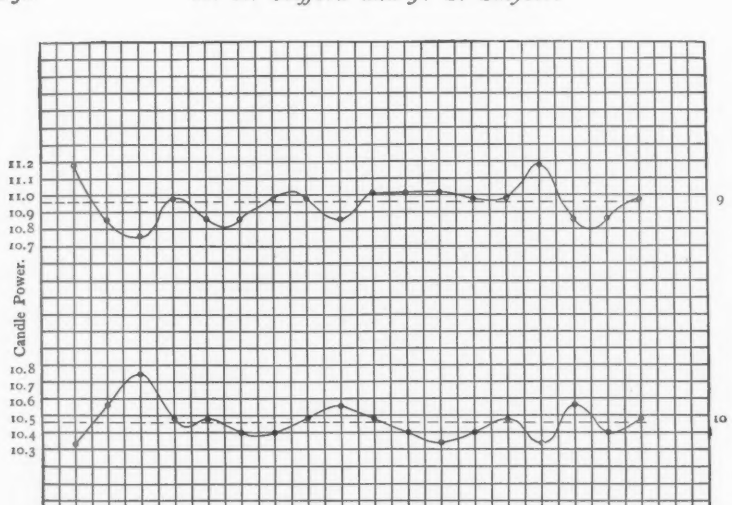
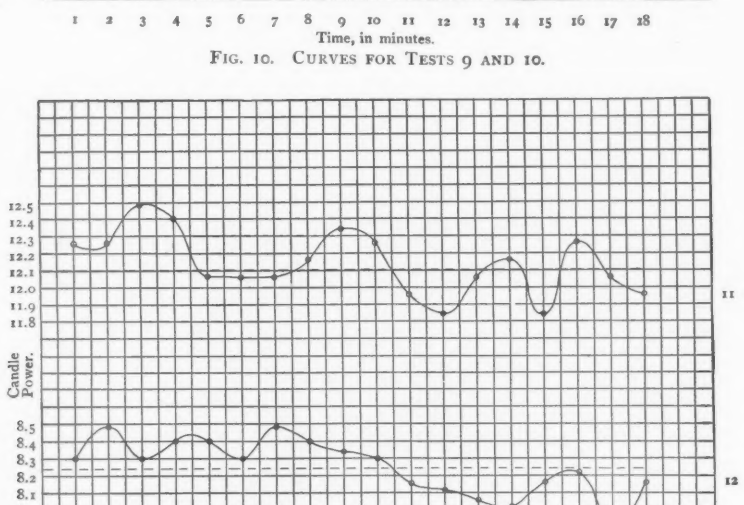


FIG. 10. CURVES FOR TESTS 9 AND 10.



Dotted line shows mean candle power.

FIG. 11. CURVES FOR TESTS 11 AND 12.

while the mean candle powers show a wide variation, proving beyond question that these variations are not due to unequal rates of gas consumption; for if we look at the table and compare tests Nos. 5 and 8, we see at once that, while their rates of gas consumption are exactly the same, their mean candle powers differ greatly; and it is instructive to note that the angular positions of the flame in these two cases differ by 90°. By referring to Curve 13 this relation is shown graphically. The intensity of light emitted in different directions in the same horizontal plane seems to follow a certain law. It would appear as though the horizontal intensities were greatest in the directions which coincide with the plane of the flame. The curve, however, shows that the directions of greatest intensity lie a little either side of this plane — a phenomenon which would lead us at once to the belief that the cross section of the flame, instead of having, as we would naturally suppose, the form shown in Figure 5 in half section, has more the form similarly shown in Figure 4.

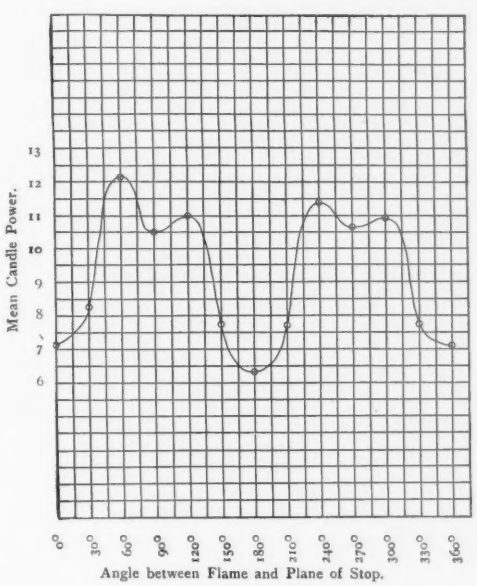


FIG. 12. CURVE NO. 13.

This seems quite reasonable when we remember that the gas issues from the burner in two small jets which impinge against each other at an angle of about 90°, and that these jets flatten out into a fan-like flame. By looking at the edge of the flame we could not, of course, hope to see this constriction at the edges, supposed to exist, for the reason that the external surface of the flame being, of course, incandescent, could give us no indication as to the shape of the surface emitting the light.

It rarely happens that a flame is symmetrical with respect to the axis of the burner, and it is quite likely that the lack of symmetry of the two crests in Curve 13 is due to the fact that the flame was non-symmetrical with respect to this axis. The same effect might, however, have been produced if the axis of the stop had failed to coincide with the horizontal axis of the flame. We are not inclined to the use of the acetylene flame as a standard of light.

ROGERS LABORATORY OF PHYSICS.
November, 1898.

A MODIFICATION OF BISCHOF'S METHOD FOR DETERMINING THE FUSIBILITY OF CLAYS, AS APPLIED TO NON-REFRACTORY CLAYS, AND THE RESISTANCE OF FIRE CLAYS TO FLUXES.[1]

By H. O. HOFMAN.

In determining experimentally the fusibility of clays, two kinds of methods may be distinguished — the direct and the indirect. Of the direct methods, that of Seger has found much favor. It consists in placing in a crucible the clay to be tested with Seger cones[2] (graded mixtures, the melting-points of which are known), and heating in a suitable furnace until a cone is found which shows the same behavior in the fire as the clay. Different apparatus is used for refractory and non-refractory clays, the standard for a refractory or fire clay being that it shall not melt before Seger cone No. 26, or at an approximate temperature of 1650° C. The details of Seger's method of comparing fire clays with his standard refractory cones Nos. 26–36 have been given in a previous paper.[3] For determining the fusibility of non-refractory clays, a special form of gas furnace[4] is required, in which, with a good pressure of gas, Seger cone No. 25, the highest of the non-refractory mixtures, can be melted down in from $4\frac{1}{2}$ to 5 hours. It may be said, however, that the melting down of cones Nos. 20–25 is often difficult.

Of the indirect methods, that of Bischof[5] has been extensively used. It consists in toning up weighed samples of the clay to be tested with increasing quantities of an intimate mixture of equal parts of chemically pure silica and alumina, and forming them into

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[1] Reprinted from Transactions of the American Institute of Mining Engineers, Buffalo Meeting, October, 1898.

[2] Thonindustrie-Zeitung, 1893, p. 1252; Berg- und Hüttenm. Zeitung, 1894, p. 119; The Clay Worker, August, 1897.

[3] *Technology Quarterly*, 8, 63.

[4] Thonindustrie-Zeitung, 1896, No. 63; Berg- und Hüttenm. Zeitung, 1897, p. 21.

[5] Dingler's Polyt. Jour., cxcvi., pp. 438, 525; cxcviii., p. 396.

small prisms, to be heated with a prism of Saarau fire clay (equal to Seger cone No. 36) to above the melting-point of wrought iron. The sample which shows the same behavior in the fire as the Saarau prism is the critical mixture, and the amount of toning-up substance needed forms the criterion of the fusibility of the clay.

Beyond question, the direct method is the simpler, since the clay need only be ground, moulded, dried and heated with standards which are always uniform and can be bought in the market at a low price. The first test is made with Seger cone No. 26, to see if the clay is refractory or not, and the work is then continued with the Deville or the Seger gas furnace. There is no drying and igniting, no weighing out of clay and of fluxes, and no intimate mixing — all of which are tedious operations. If many tests have to be made, the direct method will always be followed. The indirect method, however, has the advantage that only one standard and one furnace are required. Considering the difficulties often encountered in melting down in the gas-furnace clays that are near the refractory line, and the advantage in this respect of using only one furnace (the one for refractory clays, which is cheap, and which anyone can build for himself), and simply determining how much refractory material is necessary to bring a non-refractory clay up to the required standard, we must confess that there are conditions under which the indirect method can hold its own.

The work to be described in this paper formed part of a thesis of Messrs. J. L. Newell and G. A. Rockwell, of the Class of '95, who with much care carried out the large number of tests required to verify the method.

In these experiments the Bischof standard (Saarau clay, corresponding to Seger cone No. 36) was changed to Seger cone No. 26, which, as previously observed, forms the line of separation between refractory and non-refractory clays, the non-refractory clays being toned up until they showed the same behavior in the fire as Seger cone No. 26. This was done because it was of more interest to find out how far the non-refractory clay stood below the point of being a fire clay than how much refractory material would have to be added to bring it up to the Saarau or Seger cone No. 36 standard. Moreover, it was thus possible to work at a lower temperature, with a saving in time and gas carbon, and a prolongation of the life of the furnace lining.

The method may of course be varied. For example, the writer has toned up low-grade fire clays with bauxite until they showed the same behavior as certain high-grade fire clays, or their equivalents in terms of Seger cones.

The silica used in the experiments was quartz, ground to pass a 100-mesh sieve and purified by boiling with nitrohydrochloric acid. Upon analysis, it showed 99.88 per cent. of SiO_2, and was assumed to be pure. The alumina was obtained from the Solway Process Company, Syracuse, New York. An analysis furnished by the makers showed Al_2O_3, 98.46; SiO_2, 0.25; Na_2O, 0.50; Fe_2O_3, 0.04; loss by ignition, 0.75 per cent. As the substance readily absorbs moisture, a sample was ignited, which gave a loss of 6.42 per cent., and an allowance for this loss was made in all the work. The clays tested were kindly furnished by Professor Edward Orton, Jr. Their composition and the results of the tests are shown in the accompanying table:

ANALYSES OF CLAYS AND RESULTS OF TESTS.

Sample No.	26[1]	25[1]	3[1]	22[1]	24[1]	23[1]	1,982[2]
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	64.10	55.60	57.10	57.45	57.15	49.30	43.94
Al_2O_3	21.79	24.34	21.29	21.06	20.26	24.00	11.17
H_2O comb.	6.05	6.75	6.00	5.90	5.50	9.40	3.90
Total	91.94	86.69	84.39	84.41	82.91	82.70	59.01
F_2O_3	2.51	6.11	7.31	7.54	7.54	8.40	3.81
CaO	0.10	0.43	0.29	0.29	0.90	0.56	11.64
MgO	0.58	0.77	1.53	1.22	1.62	1.60	4.17
K_2O	2.62	3.00	3.44	3.27	3.05	3.91	2.90
Na_2O	0.03	0.09	0.61	0.39	0.58	0.17	0.71
Total	5.84	10.40	13.18	12.71	13.69	14.63	23.23
Moisture	1.10	2.65	1.30	1.90	2.70	1.20	15.66[3]
Grand total	98.88	99.74	98.87	99.02	99.30	98.54	98.00[4]
Stiffening ingredient, p. c.	20	40	60	80	80	100	180

[1] Analyzed by N. W. Lord.

[2] Analyzed by E. Orton, Jr.

[3] Includes CO_2.

[4] Includes P_2O_5, 0.10 per cent.

The method of operation was to weigh out samples of 1 gram of the clay to be tested (the moisture being allowed for); mix them severally with 0.1, 0.2, 0.3, etc., gram of the silica-alumina flux in small porcelain dishes; turn out each mixture upon a glass plate, moisten it with a 10 per cent. dextrine solution; work it with a spatula until it has acquired the right consistency, and mould it into the form of the small-size Seger cone.[1] When dried, three of them were placed in a crucible with a Seger cone, No. 26, and so heated in the Deville furnace as to melt down the Seger cone. In addition to the usual 30 grams of paper and 200 grams of charcoal, from 920 to 925 grams of gas carbon were required, with a pressure of blast of about 1 inch of water. A fusion required about 35 minutes.

In the table above, the clays are arranged according to their degree of refractoriness. Sample No. 26 requires 20 per cent. of flux to raise its melting-point to that of Seger cone No. 26; sample No. 25 requires 40 per cent., and so on.

In order to check the method, tests were made in two ways with large-size Seger cones. In the first, cones Nos. 1 to 25 were pulverized and toned up with the silica-alumina flux. It was found that 0.036 gram of the flux added to 1 gram of Seger cone substance, would raise its melting-point to that of the next higher number. In the second, two clay samples, Nos. 22 and 23, which according to indirect preliminary tests, ought to melt down at the same time as Seger cone No. 4, were placed in a graphite crucible, the bottom of which had been tamped with refractory clay, and were heated in a coke furnace with under-grate blast. In two hours the test was finished. The two clays showed in the fire approximately the same behavior as the Seger cone, thus again proving the accuracy of the method.

This modification of Bischof's indirect method may also be used for determining the resistance of fire clays or fire bricks to the corroding influence of sodium chloride, sodium sulphate, sodium carbonate, potassium carbonate, etc., to which they are exposed in glass pots, or to calcium carbonate, lead oxide, iron oxides, etc. To illustrate the operation, samples of 1.5 grams of clay are mixed severally with 5, 10, 15, etc., milligrams of flux, formed into small size Seger cones, and heated in the Deville furnace with Seger cone No. 26 in such a way

[1] *Technology Quarterly*, 8, 68.

that the Seger cone will melt. Here, again, the sample which shows the same behavior as the Seger cone will be the critical mixture, and the percentage of flux it contains will form the criterion of the clay's resistance to corrosion. It is true that the results obtained do not altogether determine the suitability of a clay for the manufacture of glass pots, as the requirements[1] of such a clay are not only that it shall resist heat and fluxes, but that it shall be highly plastic and burn dense at a comparatively low temperature. Nevertheless, the results obtained by the method form a valuable guide in the making up of mixtures. This was proved to the writer by the results with certain clays selected on account of their good behavior under the tests, which turned out a true prediction of what occurred on a large scale afterwards.

The method can, of course, be applied to a number of cases where an acid furnace material is to be exposed to the corrosion of a basic charge, and *vice versa*.

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[1] Seger-Cramer Thonindustrie-Zeitung, 1897, p. 47.

DOES THE SIZE OF PARTICLES HAVE ANY INFLUENCE IN DETERMINING THE RESISTANCE OF FIRE CLAYS TO HEAT AND TO FLUXES?[1]

By H. O. HOFMAN and B. STOUGHTON.

Before examining a fire clay in the laboratory for its resistance to heat or to fluxes, the sample is always ground to an impalpable powder. But when the clay is actually used for the manufacture of bricks, blocks, pots, etc., it is not ground to a uniform size, the particles varying from coarse grains to the finest slimes. The natural inference is that the tests with finely ground substances will give lower results than if the materials are tested just as they are going to be used. The following experiments were made to find out how far this inference is justified. The method employed for fusion was Seger's direct method,[2] and, for fluxing, the modified Bischof method described in the paper on that subject presented at the present meeting. The first question to be decided was, how large the test cones ought to be made to include representative proportions of the different sized particles composing the mixture. This was subjected to a screen analysis with the following results:

TABLE I.

Results of Screening.

	Grams.	Per cent.
Before screening	74.05	....
On 8-mesh	16.1	22.1
On 12-mesh	16.6	22.8
On 16-mesh	6.9	9.5
On 20-mesh	6.6	9.0
On 30-mesh	7.4	10.1
On 40-mesh	2.5	3.4
On 60-mesh	4.0	5.5
Through 60-mesh	12.8	17.6
Lost in screening	1.15	....

[1] Reprinted from Transactions of the American Institute of Mining Engineers, Buffalo Meeting, October, 1898.

[2] *Technology Quarterly*, **6**, 301; **8**, 63.

TABLE II.

WEIGHTS AND PROPORTIONS OF DIFFERENT SIZES IN A LARGE SEGER CONE.

Size.			Cone. No. 1.		No. 2.		No. 3.		No. 4.		No. 5.		No. 6.		No. 7.		No. 8.	
			Weight. (Grms.)	Per cent.	Weight. (Grms.)	Per cent.	Weight. (Grms.)	Per cent.	Weight. (Grms.)	Per cent.	Weight. (Grms.)	Per cent.	Weight. (Grms.)	Per cent.	Weight. (Grms.)	Per cent.	Weight. (Grms.)	Per cent.
Before disintegrating.			7.950	....	7.670	....	6.833	....	8.715	....	7.434	....	7.283	....	7.396	..	8.462	....
After disintegrating there	Remained on sieve.	8-mesh.	1.605	20.4	2.062	27.2	1.840	27.1	1.872	21.6	2.162	29.1	1.657	22.8	1.305	17.9	2.277	27.3
		12-mesh.	1.857	23.6	1.502	19.9	1.372	20.2	1.939	22.4	1.535	20.7	2.127	29.3	1.942	26.7	2.207	26.5
		16-mesh.	0.950	12.0	0.685	9.0	0.514	7.8	0.855	9.8	0 725	9.8	0.718	9.9	0.875	12.0	0.750	9.0
		20-mesh.	0.820	10.4	0.645	8.5	0 587	8.8	0.742	8 8	0 640	8.8	0.637	8 8	0.665	9.2	0.707	8.5
		30-mesh.	0.825	10.5	0.782	10.3	0.669	9.8	0.860	9.9	0.745	10.0	0.680	9.3	0.774	10.7	0.762	9.0
		40-mesh.	0.277	3.5	0.292	3.9	0.254	3.8	0.312	3.6	0.245	3.3	0.252	3.5	0.264	3.6	0.249	3.0
		60-mesh.	0.442	5.7	0.430	5.8	0.422	6.2	0.572	6.6	0.380	5.1	0.352	4.9	0.417	5.9	0.407	4.9
	Passed through sieve.	60-mesh.	1.095	13.9	1.168	15.4	1.117	16.4	1.498	17.3	0.982	13.2	0.832	11.5	1.023	14.0	0.980	11.8

After a number of preliminary trials it was decided to choose as a standard the large-size Seger cone,[1] $\frac{3}{4}$ inch at base and $2\frac{3}{8}$ inches in height. The results given in Table II show that the choice was a correct one.

This table represents eight cones made up from a sample of the mixture which had been moistened with water containing a small amount of dextrine. Each cone when dried was first weighed, then disintegrated by rubbing in a Wedgwood mortar and sifted through the same screens with which the first sizing-test had been made; the resulting different sized particles were then all separately weighed and their percentages calculated. The table shows the figures for 8-mesh and coarser sizes to be irregular. This was to be expected, as a few grains being a little larger or smaller than the average would cause a considerable difference in the percentage in view of the small weight of the cone. What went through an 8-mesh and remained on a 16-mesh screen showed more regularity; and the sizes from 16-mesh to 60-mesh give very uniform data. That the material finer than 60-mesh should again show some differences was to be expected, as the fine clay substance, adhering more or less to the coarser grains, could not be evenly separated by mere rubbing, which is all that can be used.

As the Seger cones for refractory clays, Nos. 26 to 36, are only $\frac{3}{8}$ inch at base and $\frac{25}{32}$ inch high, large-size refractory cones had to be specially made as standards for the tests. The Deville furnace, and the crucibles, with their lids and supports, were of the same general character as those described in a previous paper,[2] only the dimensions were larger. The furnace, of $\frac{1}{8}$-inch sheet iron, was 25 inches high and 12 inches in diameter; the cast-iron plate, $3\frac{3}{4}$ inches from the bottom, was 1 inch thick, had a central opening 2 inches in diameter surrounded by four rows of $\frac{1}{4}$-inch holes. The lining, of sintered magnesite from the Fayette Manufacturing Company, Pittsburg, Pennsylvania, was $3\frac{1}{4}$ inches thick at the bottom, and $2\frac{3}{4}$ inches at the top, making the inner dimensions of the furnace: diameter at bottom $5\frac{1}{2}$ inches, at top $6\frac{1}{2}$ inches, height 20 inches. The inner diameter of the air-inlet pipe was 1 inch. The outside dimensions of the crucibles were: diameter $2\frac{1}{2}$ inches, height 3 inches, thickness of wall $\frac{1}{4}$ inch;

[1] *Technology Quarterly*, **6**, 313.
[2] *Technology Quarterly*, **8**, 63.

the thickness of the lids $\frac{1}{4}$ inch; the size of the supports: diameter $2\frac{1}{2}$ inches, height $2\frac{3}{8}$ inches. The method of firing differed slightly from that pursued with the small furnace. With the latter the blast is slowly started, 30 grams of paper are ignited and pressed down into the furnace, and then 200 grams of charcoal are charged, to be followed by the required amount of gas carbon. In the large furnace the space around the crucible support was filled with small-size gas carbon (about 40 grams) before the paper (50 grams) and charcoal (250 grams) were introduced to kindle the increased amount of gas carbon. Table III gives the leading details in regard to the manner of working with the furnace.

TABLE III.

OPERATION OF THE TESTING FURNACE.

SEGER CONE.		FUEL CHARGE.			Blast pressure. (Inches water.)	Furnace. (Initial condition.)	Time required for experiment. (Minutes.)
No.	Form after fusion.	Paper. (Grams.)	Charcoal. (Grams.)	Gas carbon. (Grams.)			
26. . .	Lenticular.	50	250	2900	2	Cold.	60
31. . .	Globular.	50	250	3750	3	Hot.	50
32. . .	Globular.	50	250	4000	3	Cold.	55
33. . .	Globular.	50	250	2300	$3\frac{1}{2}$	Hot.	35
34. . .	Globular.	50	250	2400	$3\frac{1}{2}$	Hot.	40

The charcoal was passed through a small Blake crusher, set to $1\frac{1}{2}$ inches, and then sifted through a 3-mesh screen, and the fines discarded. The gas carbon was broken in the same way, and screened through a 1-mesh sieve. The under-size was passed through a 3-mesh screen to remove the fines. What remained on the 1-mesh sieve was passed through the Gates laboratory-crusher, set to $\frac{3}{4}$ inch, and was then used for filling the space around the crucible support, or reserved for the small Deville furnace.

Table IV gives the results of fusing- and fluxing-tests of mixtures just as they are to be used in making bricks, blocks, pots, etc., and of the same mixtures ground fine, as is the usual custom in laboratory tests. It shows only a slight difference in the results, and proves that, in testing fire-clay mixtures, the samples can be safely ground

fine and compared with the small-size Seger cones in the ordinary Deville furnace. Exceptional conditions only would make it necessary to test the mixtures just as they are going to be used.

TABLE IV.

COMPARATIVE TESTS OF THE SAME MATERIAL IN NATURAL CONDITION AND FINELY GROUND.

MIXTURE.		MATERIAL AS RECEIVED.		SAME MATERIAL FINELY GROUND.	
Mark.	Tested for resistance to.	Fusing test. Equal to Seger cone No.	Fluxing test. Grams of $CaCO_3$ to 1.5 of mixture.	Fusing test. Equal to Seger cone No.	Fluxing test. Grams of $CaCO_3$ to 1.5 of mixture.
A . . .	Heat.	34	....	34	....
B . . .	Heat and fluxes.	33	0.155	33	0.160
D . . .	Heat.	34	....	34	....
E . . .	Heat and fluxes.	34	0.180	34—33	0.180
H . . .	Heat and fluxes.	33—34	0.160	33—34	0.160
No. 1. .	Heat and fluxes.	31	0.100	30	0.120

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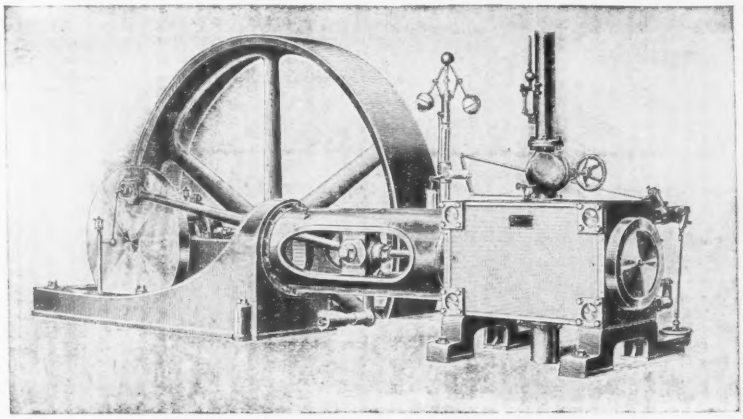

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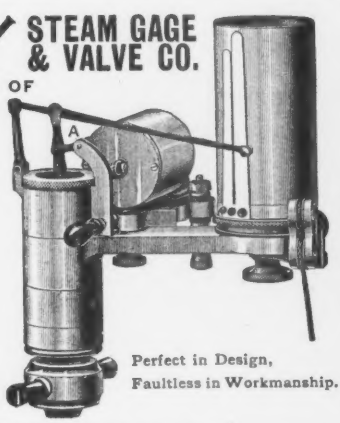

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